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Chapter 7

Modeling Agricultural Land Management to Improve Understanding of Nitrogen Leaching in an Irrigated Mediterranean Area in Southern Turkey

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Additional information is available at the end of the chapter

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Abstract

Nitrogen (N) cycle dynamics and its transport in the ecosystem were always an attracting subject for the researchers. Calculation of N budget in agricultural systems with use of different empirical statistical methods is common practice in OECD and EU countries. However, these methodologies do not include climate and water cycle as part of the process. On the other hand, big scale studies are labor and work intensive. As a solution, various computer modeling approaches have been used to predict N budget and related N parameters. One of them is internationally established Soil and Water Assessment (SWAT) model, which was developed especially for modeling agricultural catchments. The aim of this study was to improve understanding of N leaching with simulation of agricultural land management (fertilization, irrigation, and plant species) in hydrological heavily modified watershed with irrigation-depended agriculture under Mediterranean climate. The study was conducted in Lower Seyhan River Plain Irrigation District (Akarsu) of 9495 ha in Cukurova region of southern Turkey. Intensive and extensive water and nitrogen monitoring data (2008–2014), soil properties, cropping pattern, and crop rotation were used for the SWAT model build, calibration, and validation of the model.

Keywords: crop management, irrigation, nitrogen balance, SWAT, modeling

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1. Introduction

In arid and semiarid regions, freshwater resources are under the ever increasing pressure of many current issues such as population increase, economic development, climate change, and pollution [1]. Water quality is a major concern and expressed by its biological, chemical, physical, and aesthetic properties [2]. The water quality is determined by a number of factors such as electrical conductivity, pH, amount of salts, dissolved oxygen, levels of microorganisms, nutrients, heavy metals, quantities of pesticides, and herbicides [3]. These factors can lead to the problems (salinity, infiltration, toxicity, and nutrients), which are extensively present in many watersheds with irrigated agriculture [4–7].

Nitrogen leaching from agricultural land is a main pollutant in many countries in the world [7, 8]. In agricultural areas of the European Union (EU), fertilizer contribution as nonpoint source pollution to the surface water is estimated to be 55% [9]. The European Union Water Framework Directive (WFD) has issued important regulations in order to reduce the environmental impact of nitrogen due to agriculture and to keep water bodies in good quality state; based on the EU Drinking Water Directive (80/778/EEC), the accepted maximum admissible concentration for the nitrate was set as 50 mg l^{-1} [10].

On the other hand, nitrogen is an essential nutrient for adequate plant growth, and mostly used as type of fertilizer [11]. During the N cycle, it undergoes many processes in soil, water, and atmosphere level [12–14]. Nitrogen cannot be used directly by the plants and animals until it is converted into its available compounds and forms. Nitrate ions in soil are usually in dissolved form in the soil solution, and it can easily be lost to leaching as water moves through the soil profile due to the rapid dynamism [15, 16].

Understanding of nitrogen dynamics in the nature, nitrogen balance or nitrogen budget becomes more of an issue about prevention of environmental pollution and economic losses on a country basis. Nitrogen balance studies have been continued for over 170 years [17]. There are different ways of defining nitrogen budgets in empirical statistical methods, depending on the measurements and modeling. Calculation of N budget in agricultural systems by this way is a common practice in OECD and EU countries. This method does not include explaining the processes of nutrient cycle in the soil-plant-atmosphere system but follows statistical methodology at national and regional levels to determine nitrogen budget [18–20].

Measured nitrogen budgets in soil-plant-atmosphere level are based on the conservation of mass of nitrogen in the system. A previous study carried out [21, 22] aimed at evaluating nitrogen fluxes by measuring agronomic system in Akarsu Study Area in southern Turkey. As part of the findings, it was found that considerable amounts of nitrate are lost to drainage and shallow groundwater. During the study years, nitrogen budget calculations resulted in unaccounted values ranging from 40 to 60 kg N ha^{-1} [23].

As known, Mediterranean climate is characterized by mild rainy winters and hot dry summers [24]. Annual and interannual changes in dry and wet periods result in change of water balance and water level fluctuations especially in the areas where Mediterranean climate is dominating [25]. Based on the recent years' ongoing drought events and therefore water scarcity, irrigation scheduling and types need to be reevaluated. Recently, best management techniques such as

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drip irrigation [26] and rain water harvesting techniques [27] have been tried to put into practice in order to save both irrigation water and fertilizers. In the Mediterranean climate, irrigation is inevitable for maximizing the crop yield [28]. To increase crop yield and quality and at the same time to decrease the leaching below the rooting zone, managing nutrient concentrations in irrigation water is necessary, according to crop requirements [29].

Many tools are available to observe impacts of reduced irrigation and fertilization under agriculture best management practices (BMPs) scenario. Among those tools are different hydrological models capable of defining the nitrogen dynamics at the watershed level like AGNPS, AnnAGNPS, ANSWERS, ANSWERS-Continuous, CASC2D, DWSM, HSPF, KINEROS, MIKE SHE, APEX, and SWAT. And these are only a few of watershed modes, which are currently and commonly under the service of scientists and practitioners [30]. Soil and water assessment tool (SWAT) model is one of the tools developed to predict water and nutrient dynamics [31–34].

The aim of this study was to improve understanding of (a) the effects of bypass flows due to irrigation on the calibration of SWAT model, (b) irrigation return flow (IRF) and/or drainage generating processes, and (c) N leaching dynamics with simulation of agricultural land management (fertilization, irrigation, and plant species) under Mediterranean climate conditions.

2. Materials and methodology

2.1. Study area

The Akarsu Irrigation District (AID) study area is located in the Mediterranean coastal region, between 36°51′45″ and 36°57′35″ N latitudes, and 35°24′10″ and 35°36′20″ E longitudes in Turkey. The district covers an area of 9495 ha (irrigation area), and hydrological area is 11,308 ha in the Lower Seyhan Plain (LSP) and has been irrigated for over 60 years under conventional irrigation and drainage infrastructures. Until 1994, the national irrigation agency, i.e., State Hydraulic Works (DSI), was responsible for the management, operation, and maintenance of the district. Management of the irrigation and drainage system in the district was taken over by the water users in 1994. Akarsu Water User Association has been responsible for the irrigation management, operation, and repairing issues in the district since 1994. Irrigation water has been provided from Seyhan Dam (L6, L3, and L7 in **Figure 1**), in case of water shortage in the system during the peak irrigation season or if irrigation water is not diverted to the main irrigation canal through L6, then pumping station is activated and some water is diverted from Ceyhan River (Abdioglu Pumping Station, L9 in **Figure 1**). The irrigation water in Seyhan Dam has excellent water quality ($0.33 \leq EC \leq 0.50$ dS m^{-1}, EC = 0.43 dS m^{-1}). However, electrical conductivity (EC) of Ceyhan River is slightly higher than Seyhan ($0.41 \leq EC \leq 0.80$ dS m^{-1}, EC = 0.58 dS m^{-1}). The drainage water flows through open ditches along the downstream areas and finally discharges into the Mediterranean Sea.

In the study area, the Mediterranean climate is dominant, summers are hot and dry winters are mild and rainy. Precipitation is mostly in the form of rain (average of 659 mm) that usually falls during winter and spring [35]. Temperature in June, July, and August is very high (average 33.3°C); winter months are cool with reasonable temperatures (average 10.5°C) [36]. While the

long-term (1929–2014) mean temperature is 27.4°C, the long-term mean total evaporation is about 1559 mm annually (coefficient of variation <27%). According to the long-term data, soil moisture and soil temperature regimes are defined as xeric and thermic by Ref. [37].

In the area, 1st April–30th September is defined as irrigation season (IS), while 1st October–1st April is defined as nonirrigation season (NIS). However, these dates may change a little by precipitation and climatic conditions.

The soils of Akarsu consist of 11 different soil series (Incirlik, Arikli, Yenice, Innapli, Arpaci, Canakci, Mursel, Ismailiye, Golyaka, Gemisure, and Misis). The model-related physical and chemical characteristics of these soil series are recorded from Ref. [37] and verified to be used in the SWAT model. As an example, only the data of six common soil series are given in **Table 1**. Arikli (29.5%), Incirlik (25.3%), and Yenice (12.2%) series cover 67% of the entire study area. Innapli (1.03%) and Mursel (0.7%) have got the minimum distributions.

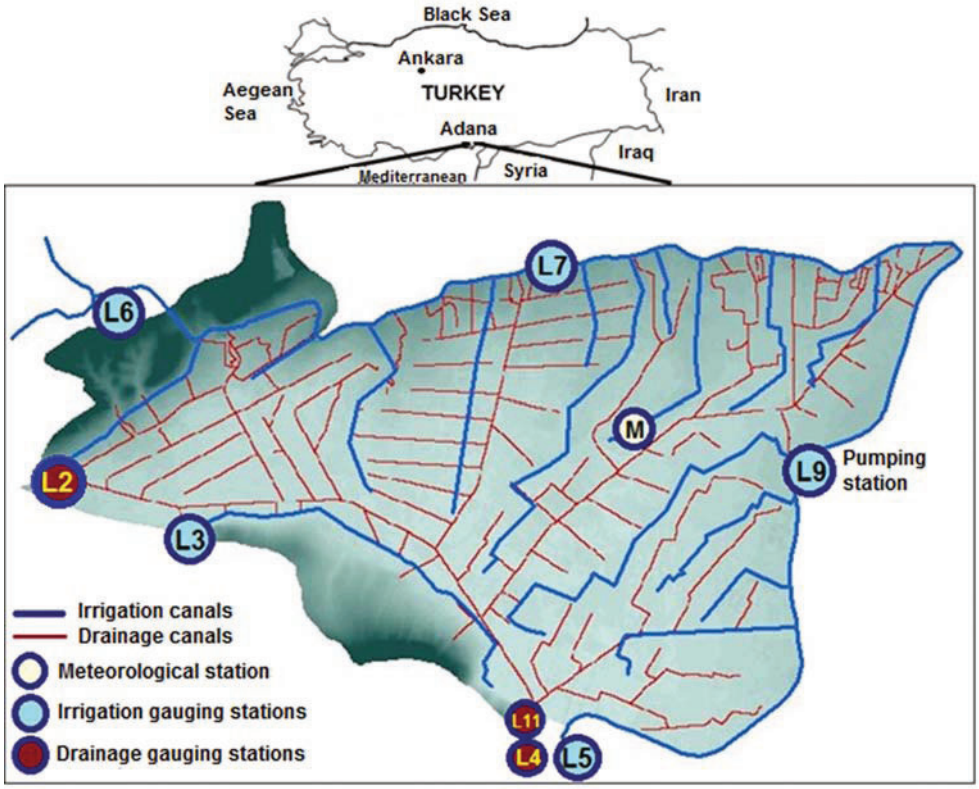


Figure 1. The Akarsu study area.

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Soil series	Depth (cm)	Texture class[1]	Sand	Silt	Clay	Rock	BD[2]	OM[3]	AWC[4]	K_{sat}[5]
Incirlik	0–13	C	12	26	62	2.5	1.4	1.25	0.226	2.8
	13–78	C	16	24	60	2.5	1.6	0.62	0.233	0.55
	78–150	C	14	26	60	1.0	1.6	0.33	0.301	2.9
Arikli	0–13	SiC	8	29	63	3.5	1.3	1.25	0.268	0.63
	13–30	SiC	8	30	62	2.5	1.4	0.62	0.268	0.16
	30–57	SiC	4	29	67	1.5	1.4	0.33	0.287	0.4
	57–100		7	31	62			1.24		
	110–114		6	31	63			0.91		
	114–150		3	42	55			0.84		
Yenice	0–14	C	14	32	54	2.5	1.57	1.61	0.218	191.5
	14–32	C	12	30	58	1.8	1.59	1.21	0.259	328
	32–92	CL	14	30	56	1.0	1.48	0.80	0.219	729
	92–118		18	31	51			0.54		
Misis	0–24	C	25	23	52	1.5	1.63	1.61	0.212	3.33
	24–45	C	25	21	54	1.5	1.53	1.21	0.232	1.7
	45–64	SCL	23	21	56	1.7	1.49	0.93	0.247	1.7
	64–86		22	19	59		1.51	0.80		
	86–120		22	18	60			0.67		
	120–140		51	23	26			0.13		
Canakci	0–10	SL	25	47	28	1.5	1.51	1.37	0.208	23.9
	10–39	CL	21	55	24	1.8	1.34	1.17	0.171	16.8
	39–60	CL	29	39	32	1.6	1.58	1.50	0.157	11.5
	60–73		35	43	22			0.39		
	73–94		28	49	23			0.46		
	94–112		13	52	35			0.63		
	112–150		22	48	30			0.36		
Gemisure	0–21	C	2	26	72	1.5	1.45	1.53	0.15	2.4
	21–36	C	3	24	73	1.5	1.35	1.47	0.15	2.4
	36–78	C	3	22	75	1.8	1.39	1.34	0.15	2.4
	78–120		4	19	77			1.07		

[1] L, loam; C, clay; S, sand; Si, silt.
[2] Bulk density (g cm^{-3}).
[3] Organic matter (%).
[4] Plant available water capacity (mm H_2O mm soil $depth^{-1}$).
[5] Saturated hydraulic conductivity (mm h^{-1}).

Table 1. Soil properties for the Akarsu study area.

2.2. Database

The SWAT model input data, which is used in the project, is listed in **Table 2**. The 25 m resolution digital elevation model was derived by Akgul [38]. The chemical and physical properties of soils were gathered from Ref. [37], and these data were checked and verified with various measurements and laboratory analysis. Soil albedos and values of USLE were calculated by using the equations given in Ref. [39]. Soil series characteristics were interpreted and soil hydrologic group codes were assigned to each soil series based on the run-off generating characteristics. Daily irrigation return flow rates were determined by the data observed at the Inlet (L2, L11) and Outlet (L4) drainage monitoring stations. Nitrate concentrations were determined in water samples collected via automatic sampler located in L4 gauging site.

Data type	Resolution	Source	Description/properties
Topography (DEM)	25 m × 25 m	[38]	Elevation, slope, channel slopes, overland
Land cover/land use	10 m × 10 m	[35]	Land cover, land use classification
Soils	10 m × 10 m	[37]	Spatial soil variability, soil types, soil physical properties; bulk density, texture, saturated hydraulic conductivity classes, etc.
Drainage network		[35]	Drain spacing, length of cannels, drainage divides, etc.
Climate data		Adana State meteorological station and meteorological monitoring gage (L8)	Daily precipitation, temperature (max., min.), solar radiation, wind speed, relative humidity
Agricultural management practices		Farmer questionnaires in Akarsu and field surveys (face to face)	Planting, fertilizer application rates and timing, tillage, harvesting dates, irrigation water management and amount, etc.
Daily irrigation return flow rate (outlet)		1 monitoring and sampling station (L4 in **Figure 1**)	Daily flow (m^3 day^{-1})
Daily irrigation return flow rate (inlet)		2 monitoring and sampling stations (L2, L11)	Daily flow (m^3 day^{-1})
Daily irrigation return flow nitrate load (outlet)		1 monitoring and sampling station	Daily NO_3-N load (kg day^{-1})
Daily irrigation return flow nitrate load (inlet)		Two monitoring and sampling stations (L2, L11)	Daily NO_3-N load (kg day^{-1})

Table 2. Model input data and the sources.

2.3. Agricultural land management

The SWAT model has eight main components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management [30]. Watershed

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hydrology is affected by vegetation types, soil properties, geology, terrain, climate, land use practices, and spatial patterns of interactions among these factors [40].

The area is suitable for various agricultural productions with its favorable climatic and productive land conditions. Cropping pattern data have been assessed since 2006, and the likely crop rotation has been decided for the modeling practices. According to the data, land use and cropping pattern varied from year to year depending on the market and cultivation conditions. Based on the assessments, we have set five different crop rotations plus fruit orchards and citrus plantations (**Table 3**), which have been well adopted by the farmers in the region. Based on the recent years' evaluation, the main crops in the area were wheat, corn, citrus, cotton, and vegetables (**Table 3**). Agricultural management practices were determined based on the current surveys carried out at the local field and farmers' level.

Year	Soil tillage and crop growing period	Crops	Inorganic nitrogen fertilizer (kg elemental N ha^{-1})	Irrigation water (mm)
Rotation 1				
1	16th Mar.–16th Sep.	C1[1]	385	1168
1/2	20th Nov.–07th June	WW[2]	230	383
2/3	15th June–10th Oct.	S2[3]	120	870
3	16th Mar.–16th Sep.	C1[1]	385	1168
3/4	20th Nov.–1st June	WW[2]	230	383
4	15th June–10th Oct.	S2[3]	120	870
Rotation 2				
1	15th June–10th Oct.	S2[3]	120	870
2	16th Mar.–16th Sep.	C1[1]	385	1168
2/3	20th Nov–07th June	WW[2]	230	383
3	15th June–10th Oct.	S2[3]	120	870
4	16th Mar.–16th Sep.	C1[1]	385	1168
Rotation 3				
1	15th Mar.–15th Oct.	Co[4]	290	1535
2	15th Apr.–10th Sep.	P1[5]	210	1068.33
3	15th Mar.–15th Oct.	Co[4]	290	1535
4	16th Mar.–16th Sep.	C1[1]	385	1168.33
Rotation 4				
1	15th June–25th Oct.	P2[6]	210	800
2	16th Mar.–16th Sep.	C1[1]	385	1168.33
2/3	20th Nov.–07th June	WW[2]	230	383.33
3	15th June–25th Oct.	P2[6]	210	800
4	15th Mar.–15th Oct.	Co[4]	290	1535
4/1	20th Nov.– 07th June	WW[2]	230	383.33

Year	Soil tillage and crop growing period	Crops	Inorganic nitrogen fertilizer (kg elemental N ha^{-1})	Irrigation water (mm)
Rotation 5				
1	20th June–30th Oct.	C2[7]	330	858.33
2	16th Mar.–16th Sep.	C1[1]	385	1168.33
2/3	20th Nov.–07th June	WW[2]	230	383.33
3	20th June–30th Oct	C2[7]	330	858.33
4	15th Mar.–15th Oct.	Co[4]	290	1535
4/1	20th Nov.–07th June	WW[2]	230	383.33
Orchards and citrus[+]				
Perennial	15th Mar.–8th Oct.	Orchards	250	1238.33
Perennial	1st Oct.–27th Sep.	Citrus	335	1040

[1] C1, first crop corn.
[2] WW, winter wheat.
[3] S2, second crop soybean.
[4] Co, cotton.
[5] P1, first crop peanut.
[6] P2, second crop peanut.
[7] C2, second crop corn.
[+] All kinds of operations done to orchards and citrus between these dates.

Table 3. Agricultural land management crop rotations used in the model.

The proportion of this land use type in the hydrological model area (11,308 ha) is: AGRL (Agricultural Area) (64.56%), ORAN (Citrus) (21.49%), ORCD (Orchards) (1.74%), WPAS (Winter Pastures) (9.20%), URMD (Settlement area (Medium Density)) (1.64%), and URLD (Settlement area (Low Density) (1.36%)). The agricultural areas in the study area contain various annual crops such as first crop corn, second crop corn, winter wheat, first crop soybean, second crop soybean, peanuts, and cotton.

2.4. SWAT model description

The soil and water assessment tool is one of the recent models, known as a catchment area or watershed scale model, developed by Arnold et al. [31] and improved in the last 30 years [41]. It is a semidistributed hydrological model, which is a physically based, long period of simulation, lumped parameter, and derived from agriculture management systems models such as CREAMS, EPIC, and GLEAMS [41, 42]. The model separates selected basin to subbasins and hydrologic response units (HRU) comprised of identical hydrological properties such as land use, soil, and slope [43]. SWAT is an efficient tool to predict the impact of nitrogen cycle and land management practices on water, sediment, nutrient, and pesticide with the ArcSWAT module [44]. The nitrogen cycle can be represented by the SWAT model in the soil profile and

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shallow aquifer. SWAT comprises two pools that are inorganic forms of nitrogen (NH_4^+ and NO_3^-) and three pools that are organic forms of nitrogen in the soil [45–47]. Nitrate and organic N into the nitrogen cycle, N removal from soil to water sources, and amounts of NO_3-N included in lateral flow, runoff, and percolation can also be represented by the SWAT model [45]. The SWAT model could sufficiently predict sediment and nutrient statuses as well as tile drainage NO_3-N losses [48, 49].

The prediction of land management practices is important as well as nitrogen cycle to provide the progress of future socioeconomic stability and sustainable use of natural resources and to search the impact of human activities on a given basin [50, 39]. SWAT has a capability to estimate the effects of land management practices on sediment, water, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over a long-term time [43, 51–54].

2.5. Calibration process of the base model

Calibration and validation are key processes in reducing the uncertainty and increasing user experience in its predictive results, making the software a practical model and leading to user competence.

The adjustment of model parameters is described as calibration. These parameters are associated with checking results toward observations to assure the same response in time [55]. A number of calibration techniques, comprising manual calibration method and automated method, improved for the SWAT model [39]. The model calibration is done manually and finalized by SWAT-CUP (Calibration and Uncertainty Programs). SWAT-CUP is an interface known as "automated model calibration method" that was improved for SWAT to connect with a link between the input and output of a calibration program and the model [56]. The SUFI-2 algorithm was used for sensitivity analysis, model calibration, and validation process. The warm up period was set for 1 year.

The calibration of SWAT is completed in three phases [39]. The first phase is the determination of most sensitive parameters (such as Alpha_Bf, Canmx, Ch_K2, Ch_N, Cn2, Esco, Gw_Delay, Gw_Revap, Gwqmn Surlag for flow, and Nperco, Al1 CMN, Hlife_Ngw for nitrate-nitrogen) [57]. The second phase is model calibration with use of statistical methods such as Pearson coefficient of correlation (R^2), Nash-Sutcliffe efficiency (ENS), and percent bias (PBIAS). The final phase is validation process for hydrological calibration and nitrogen calibration of the model.

Validation, known as the part of simulation, can be done without modifying any parameter values adjusted during calibration for a different time series to input data and also for the same time period at a different spatial location [58]. In this study, daily measured values of irrigation and irrigation return flows, and also nitrate loads for the year of 2008 were used for the warm up period. SWAT was calibrated with daily values over a 4-year period from 2009 to 2012 for hydrological years and used daily values for nitrogen. The 2-year time period from 2013 to 2014 was used for validation of hydrology and nitrogen.

3. Results and discussion

3.1. Calibration of drainage flows

Calibration process of the model used in this specific research was first completed with hydrologic calibration and followed by the drainage nitrogen. In general, calibration and validation of water quality models are typically performed with data collected at the outlet of a watershed to be able to assess possible pollution risks. In Akarsu, daily measured data were used during the model processes. The most sensitive parameters for hydrologic calibration process were SURLAG, GW_Delay, Revapmn, GW_Revap, and Esco (**Table 4**), while Nperco, Cmn, Hlife, and Ngw are the sensitive ones for nitrogen calibration.

Parameter	File extensions	Explanation
Alpha_BF	.gw	Base flow recession factor, days
GW_DELAY	.gw	Groundwater delay, days
SURLAG	.bsn	Surface runoff lag coefficient, days
ESCO	.bsn	Soil evaporation compensation factor
GWQMN	.gw	Threshold depth for ground water flow to occur, mm
GW_REVAP	.gw	Groundwater "revap" coefficient
Ch_N2	.rte	Manning's n
SOL_AWC	.sol	Available water capacity
CN2	.mgt	SCS curve number, antecedent moisture condition II, for crop land use
REVAPMN	.gw	Threshold water depth in shallow aquifer for percolation to deep aquifer to occur
CH_K2	.rte	Effective hydraulic conductivity in main channel alluvium
NPERCO	.bsn	Nitrate percolation coefficient
HLIFE_NGW	.gw	Half-life of nitrate in shallow aquifer (days)
CMN	.bsn	Rate factor for humus mineralization of active organic nutrients (N).
AI1	.wwq	Fraction of algal biomass that is nitrogen (mg N mg alg^{-1}).

Table 4. SWAT input parameters for river flow and nitrogen calibrations.

Based on the model outputs, the SWAT model is reliable enough to be used in nonnatural catchments such as Akarsu Irrigation District where drainage network is not topography-driven but man-made. Additionally, hydrologic water dynamics such as inflows, outflows, and the whole water balance are well defined since 2006. The area is affected by routine agricultural management activities, i.e., irrigation and fertilization in specific.

Three recommended quantitative statistics, determination (R^2), Nash-Sutcliffe efficiency (NSE), and PBIAS, in addition to the graphical techniques for visual examination have been used to assess the hydrologic model performance [59], i.e., model calibration and validation. These performance indicators of the model (R^2, NSE, and PBIAS) during calibration period of 2009–2012 have been found as 0.62, 0.57, and 6.3, respectively (**Table 5**). Typically, values of R^2

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greater than 0.50, while values of NSE between 0.0 and 1.0, and values of PBIAS ±25% for streamflow calibration are generally considered as acceptable levels [59]. In addition, model validation was made by utilizing the daily data for 2013 and 2014 period. The performance statistics for the validation period were 0.67, 0.59, and −10.04 for R^2, NSE, and PBIAS, respectively (**Table 5**).

Variable	R^2	NSE	PBIAS
Calibration (2009–2012)			
Daily drainage flow	0.62	0.57	6.3
Daily nitrogen loss	0.47	−0.63	88.1
Validation (2013–2014)			
Daily drainage flow	0.67	0.59	−10.04
Daily nitrogen loss	0.50	−0.20	72.9

Table 5. Objective function statistics for drainage flow and nitrogen in drainage.

Descriptive statistics for observed and simulated (calibration and validation) were resented in **Table 6**, indicating that model performance was satisfactory with the mean values of 3.51, 2.98 $m^3\ s^{-1}$ for calibration period and 2.71 and 2.98 for validation period. Similarly, other descriptive statistics for observed and simulated flow values were in good agreement.

The visual examination of observed versus predicted drainage flows for the calibration (**Figure 2**) and validation periods (**Figure 3**) indicated adequate calibration and validation. Therefore, SWAT simulations and observed data were in good agreement visually and statistically. SWAT-CUP automatic calibration results for the sensitive parameters were presented in **Table 7**. These parameters are reasonable enough to accept performance of the model [56] in a well-defined agricultural catchment of Akarsu where anthropogenic factors affecting hydrological processes are very preponderant.

Because the study area is under irrigation in dry periods of the year, it was necessary to consider irrigation amounts of field and horticultural crops grown in the region. Therefore, during the calibration period, irrigation requirements of the crops were estimated by using universal reference evapotranspiration method of Penman-Monteith. Then, using the crop coefficients of FAO [60], net irrigation requirements of irrigated crops were obtained and used in management files as a model input. For the calibration, the created base model with net irrigation amounts and routine fertilizer rates were saved in crop rotations. The actual irrigation bypass flows were determined through running different simulations by adapting calibrated SWAT parameters given in **Table 7**. Finally, it was determined that 40% of the total diverted irrigation water to the district at any time was directly draining into the drainage system as bypass flow.

3.2. Calibration of nitrogen in drainage water

After calibrating the hydrologic part of the model with a successful performance, nitrate simulation was confidently applied with the appropriate water parameters. All the nitrogen inputs were incorporated in the management files as fertilizer, water, and soil point sources.

Average daily NO_3-N loads (kg day^{-1}) were selected as water quality parameter and calculated based on daily discharge data (m^3 day^{-1}) at L4 gauging station (outlet).

	Calibration period (2009–2012)		Validation period (2013–2014)	
	Observed	**Simulated**	**Observed**	**Simulated**
	Drainage flows (m^3 s^{-1})			
Mean	3.51	2.98	2.71	2.98
Median	3.48	2.69	2.74	2.62
Mode	1.04	1.86	1.23	2.35
Standard dev.	2.02	1.93	1.45	1.46
Kurtosis	5.54	10.43	−1.01	−0.62
Skewness	1.70	1.96	0.33	0.38
Minimum	0.73	0.09	0.58	0.31
Maximum	14.06	18.65	6.05	7.27
CV%	58	65	54	49
	Nitrogen in drainage (kg d^{-1})			
Mean	1810.2	443.1	938.7	552.6
Median	1376.4	243.9	774.0	457.6
Mode	1775.5	229.3	–	1135.0
Standard dev.	1659.0	639.9	608.9	533.2
Kurtosis	15.8	21.9	5.8	57.8
Skewness	3.4	4.0	2.0	5.8
Minimum	143.4	10.4	64.9	39.7
Maximum	14024.7	6403.0	4826.0	7599.0
CV%	92	144	65	96
Sample size (*n*)	1461		730	

Table 6. Descriptive statistics of drainage flows and nitrogen loads in drainage for observed and simulated during calibration and validation periods.

Objective function statistics, R^2, NSE, and PBIAS in specific, for nitrogen in drainage were defined as 0.47, −0.63, and 88.1% for the calibration and 0.50, −0.20, and 72.9% for validation, respectively (**Table 5**). As indicated by Moriasi et al. [59], the PBIAS ±70% for N is accepted as a performance criteria.

Average daily NO_3-N loads (kg day^{-1}) of the selected water quality parameter was also calculated based on daily discharge data (m^3 day^{-1}) at L4 gauging station at the outlet of the district. Based on the graphical presentation in **Figures 4** and **5**, overlapping of the both measured and calibrated lines for N cannot be considered as perfect because nature and

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dynamics of N in the whole system, even though the statistics are reasonably acceptable. Similar underestimation with the data of only 2009 and 2010 was also recorded in the same location [38]. It is important to point out that calibration and validation of the model are sensitive to time periods, instead of using daily data, monthly data were more suitable to modeling purpose of N [61].

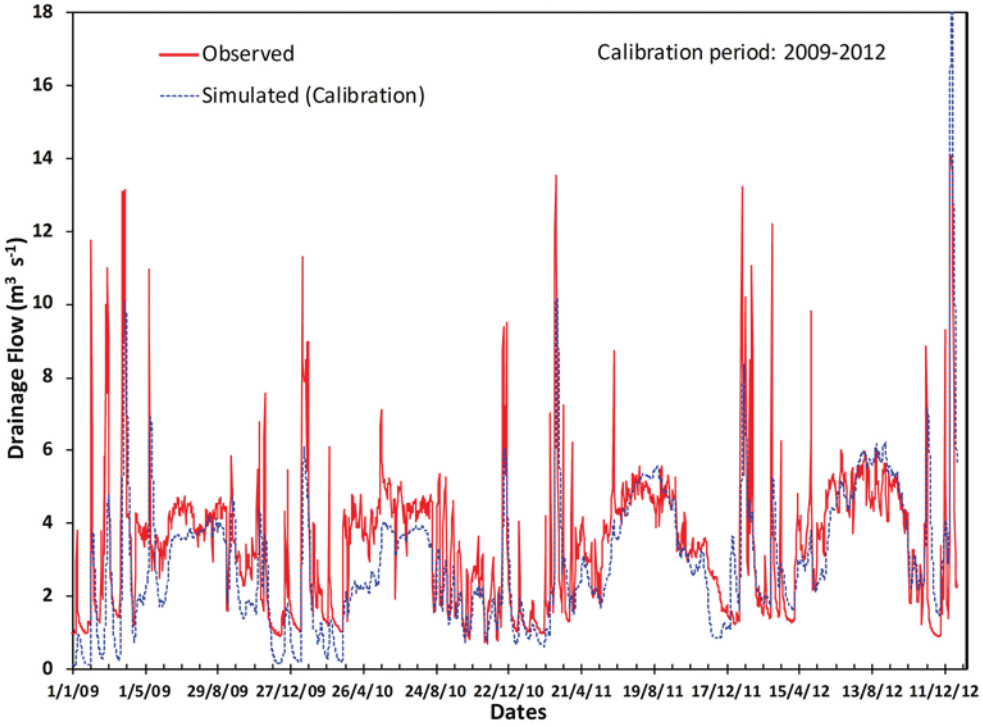


Figure 2. Daily drainage discharge (m^3 s^{-1}) calibration for the Akarsu catchment outlet L4.

This basin is not natural instead it is a man-made hydrologically well-defined area in a semiarid Mediterranean region where it is subjected to intensive irrigation and fertilizer applications by anthropogenic activities. Imported N loads by irrigation water, rainfall, and inorganic fertilizer inputs make the calibration and validation difficult and relatively weak. There are three district-specific conditions in the area to be pointed out for nitrogen and nitrogen balance: the canals being open despite high rates of ET, irrigation also taking place outside of irrigation season, and the possible loses of irrigation water to drainage.

In terms of management practices, there are two planting seasons in a year; the crop rotations used in the model include all the planting and harvesting dates. Except for perennial crops, the crop pattern (land use) varies from year to year. The model permits use of only one land use map in HRU delineation; for this reason, rotation calendars were made to be utilized within

the model. Farmer behavior and knowledge are diverse, and the use of nitrogen fertilizers and irrigation is intense.

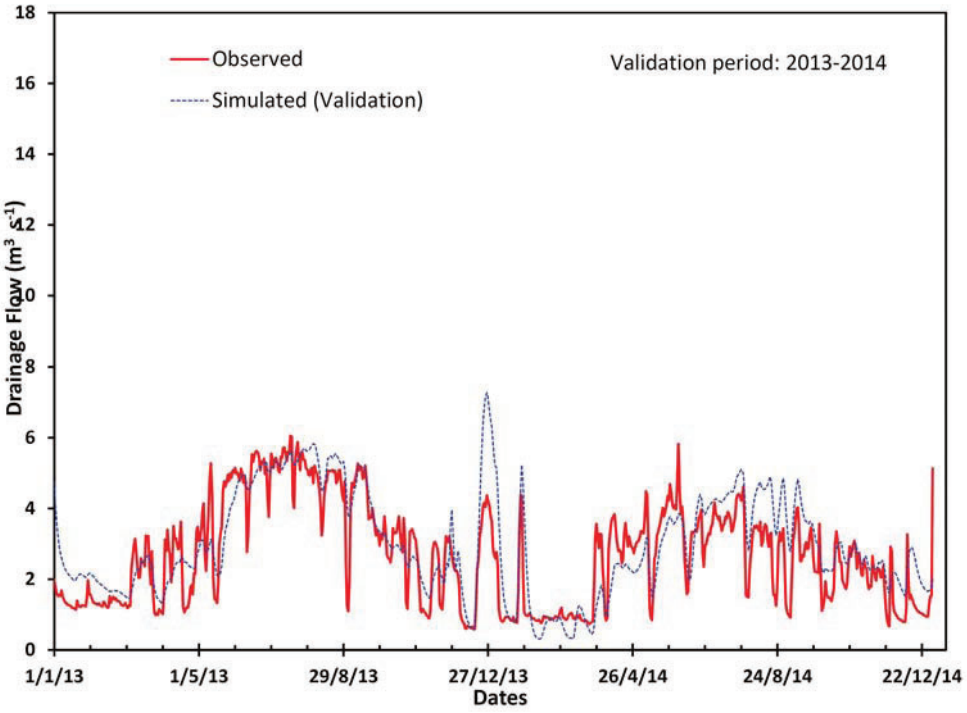


Figure 3. Daily drainage discharge ($m^3\ s^{-1}$) validation for the Akarsu catchment outlet at L4.

Parameter	Default	Range	Calibrated values
CN2	83	35–98	73.9
Alpha_BF	0.048	0–1	0.55
GW_Delay	31	0–500	36.08
Gwqmn	1000	0–5000	4187.5
Surlag	4	1–24	0.42
Esco	0.95	0–1	0.837
Revapmn	750	0–1000	488.75
Ch_K2	0	−0.01 to 500	378.75
Gw_Revap	0.02	0.02–0.2	0.089
Ch_n2	0.014	−0.01 to 0.3	0.266

Table 7. Sensitive hydrologic model parameters for SWAT.

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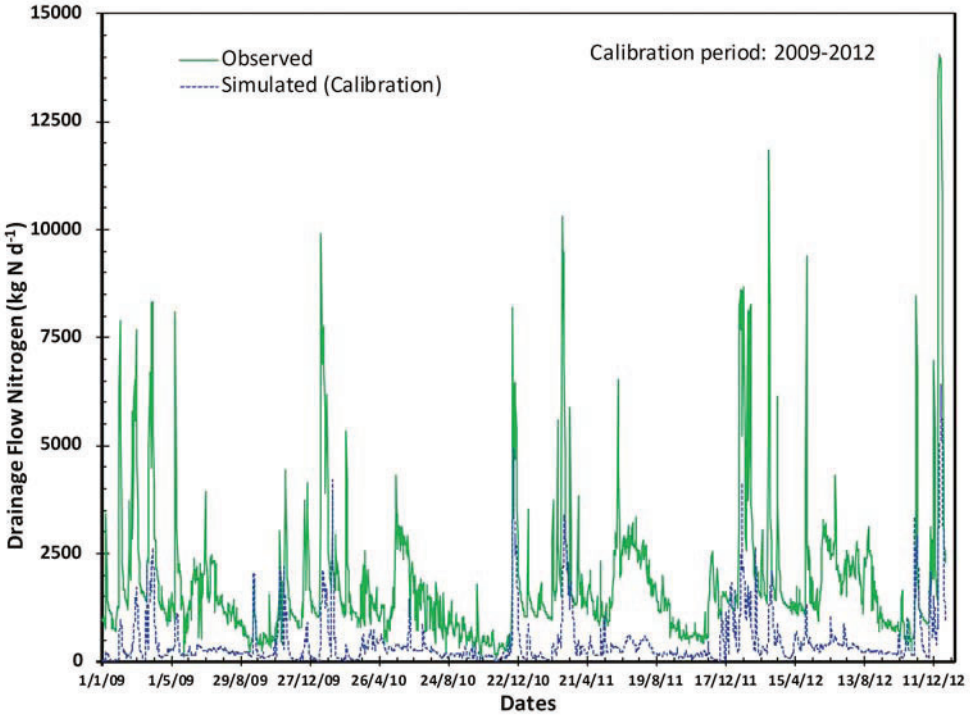


Figure 4. Nitrogen load (kg day^{-1}) at L4 (outlet) calibration and validation period on monthly level.

3.3. Nitrogen balance

Nitrogen calibration was carried out on daily basis. Average daily NO_3-N loads (kg day^{-1}) of selected water quality parameter were calculated based on daily discharge data (m^3 day^{-1}) at L4 gauging station. **Table 5** and **Figures 4** and **5** created for nitrogen did not show a strong relationship between measured and simulated values. One of the main reasons is that for hydrologic reasons inclusion of the two hilly pasture areas (**Figure 1**) into the 9495 ha hydrologically well-defined Akarsu irrigation district by extending the area to 11,308 ha. Therefore, when the actual N inputs were distributed in a larger area the prediction became lower. Also, since the soils are climatically suitable to nitrification, greater amount of nitrogen especially from the inorganic fertilizers may be quickly transformed to nitrate in a very short time period and leached to the drainage [62]. As also discussed by Abbaspour et al. [56], amount of nitrogen fertilizer leached below the root zone, which is 0–90 cm in the study, is under-estimated. In addition, fertilizer application level may be higher than that of the recorded from our three consecutive survey data. Therefore, it may cause higher measured NO_3 concentrations in drainage. Overall, since the irrigated area is under very intensive agricultural management practices including irrigation and very dynamic fertilization, it is quite possible to underestimate the N leaching to the drainage. For example, SWAT model prediction was very successful for calibration (and validation) of rivers accounting the dynamics of nitrate transport [56].

Nitrogen balance variables are given in **Table 8**. The sums of nitrate nitrogen leached from the soil profile in kg NO_3–N(NO3L) and N uptake by plants (NUP) from 2009 to 2014 are reasonably in agreement with the amount of applied nitrogen (N APP). The remaining inputs in the so-called man-made research area are coming from the N content of irrigation water, rainfall, mineralization of soil organic matter, and transforms of N forms into readily available NH_4^- and NO_3. Based on the climatic conditions, amount of rainfall, thus leaching to drainage, and groundwater, varies year to year. For example, in 2013, total rainfall was 349 mm, which was the lowest figure among the other years of the study (ranged 349–951 mm). The reflection of this unusual rainfall was clearly performed in **Figure 5**, which is for the simulation period. **Figure 4** clearly indicates that impacts of rainfall in winter and irrigation applications in

	Nitrogen balance variables (kg N ha^{-1} $year^{-1}$)		
Year	**N_APP[1*]**	**NO3L**	**NUP**
2009	329.2	196.8	270.0
2010	368.1	212.8	228.3
2011	310.9	234.7	181.3
2012	368.1	256.3	175.1
2013	329.2	159.2	277.7
2014	368.1	249.3	254.6

[*] N_APP, NO3L, and NUP stand for applied, leached, and taken-up nitrogen at the catchment level.

Table 8. Temporal variability of nitrogen balance by SWAT modeling for the Akarsu region (2009–2014).

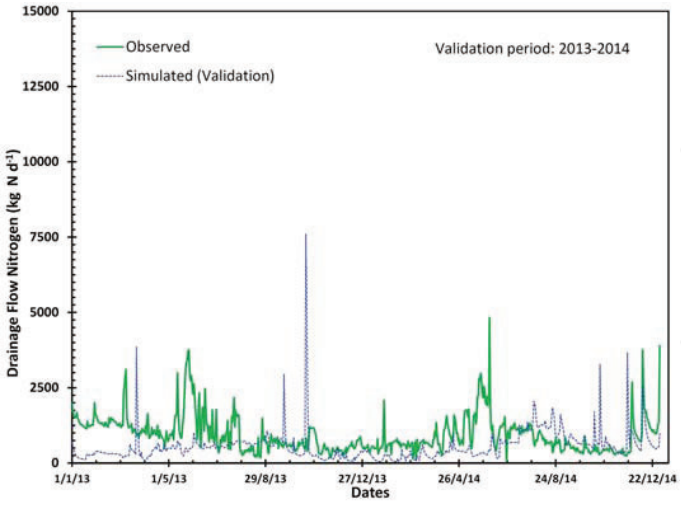


Figure 5. Nitrogen load (kg day^{-1}) at L4 (outlet) calibration and validation period on monthly level.

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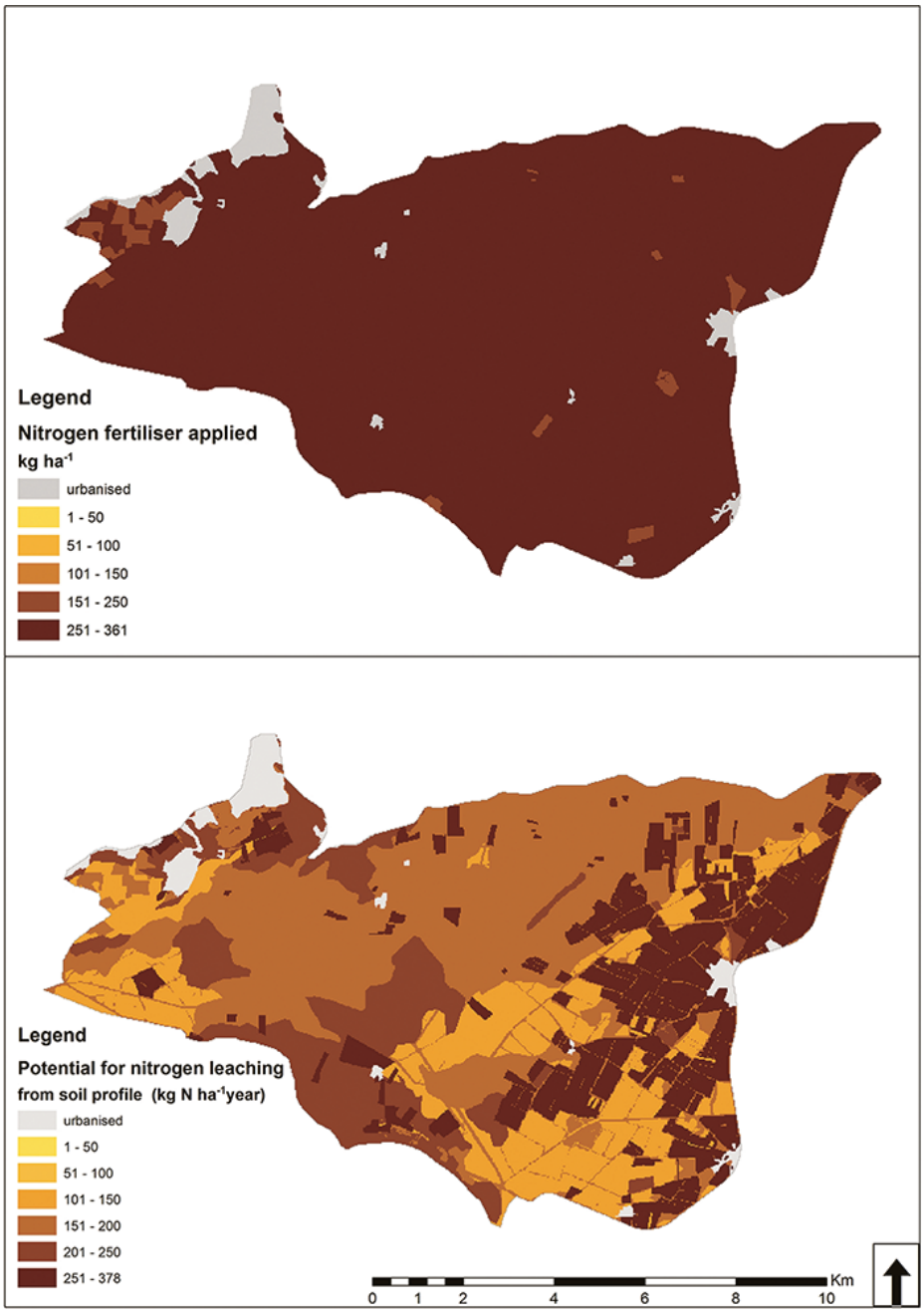


Figure 6. Comparison between average nitrogen fertilizers applied (kg ha^{-1}) and potential for nitrogen leaching (kg ha^{-1}) below the bottom of the soil profile in Akarsu study area in the period between 2009 and 2014.

summer are the most important drivers of the N leaching. Conflicting performance ratings of N calibration seen in **Figures 4** and **5** might be attributed to above mentioned two drivers. In addition, routine fertilizer applications are exceedingly high than the recommended levels, i.e., 380 kg N ha^{-1} is applied to corn while only 240 kg N ha^{-1} is the expert recommendation for corn in the region [63]. This results in high potential for nitrogen leaching (**Figure 6**).

4. Conclusions

Distributed watershed models are known as the very powerful tools both for scenario development and for simulating the effects of watershed dynamics management on soil and water resources. This study was aimed to improve understanding of (a) the effects of bypass flows due to irrigation on the calibration of the SWAT model, (b) irrigation return flow and/or drainage generating processes, and (c) N leaching dynamics with simulation of agricultural land management (fertilization, irrigation, and plant species) under the Mediterranean climate conditions. To this aim, the research was conducted in an irrigated agricultural catchment of Akarsu irrigation district. Visual examination of data used in modeling has indicated that drainage flows and nitrogen-leaching processes are not governed by the natural processes in the catchment but mostly by anthropogenic activities.

Model calibration and validation were carried out to determine the most sensitive and appropriate parameter values for the drainage flows generated by the agricultural catchment. Although daily flow data were used in modeling, quantitative model performance evaluation statistics (R^2, NSE, and PBIAS) revealed clearly that the calibrated SWAT model produced rather satisfactory simulation results at the catchment outlet in wet, average, and dry years. In the irrigated catchment, irrigation water losses directly from irrigation channels to drainage ditches, i.e., bypass flows, has direct influence on calibrating hydrologic part of the SWAT model. In this case, the SWAT model findings helped us to highlight that almost 40% of diverted irrigation water has been recklessly squandered in the irrigation scheme. It is almost impossible to quantify bypass flow magnitudes in such irrigation system without using any modeling tools.

Furthermore, modeling exercises showed that the SWAT model run results were sensitive on crop rotations due to the fact that runoff by precipitation and irrigation applications are affected by the land use and land cover types. Contrary to the expectations, daily nitrate modeling results were not able to yield rather satisfactory model performance statistics, indicating that simulated daily nitrogen loads data in drainage were not sufficiently matched with the measured ones. Visual evaluation of measured and simulated nitrogen graphs showed implicit signals that measured nitrogen data might involve some inherent uncertainties and irregularities at the catchment level. Based on the findings, as highlighted in the literature [59], we concluded that model performance can be improved to some extent by increasing the time step from daily to monthly or yearly level for the nitrogen data with involves inherent uncertainties. These uncertainties should be considered when calibrating, validating, and evaluating watershed models because of differences in inherent uncertainty between measured flow, sediment, and nutrient data.

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Improved fertilization practices are not only necessary for farmer's economy but also crucial for preserving soil and water resources. In recent years, especial soil analysis in the study area became a very useful tool for fertilizer subsidizes and expert recommendations. However, recommendations can not only be related to and designed by the soil analysis, it should be comprehensively evaluated in a broader environment. At this stage, a suitable model performance enables modeling more sensitive management practices like the fertilizer rates.

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