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Development of a Hydrodynamic Model for Regulating Water Drainage of Reservoir and Water Resources Management, Lamtakong Watershed of Thailand

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ABSTRACT

The goal of this research was to develop a hydrodynamic model (HDD-M) for water resource management in the Lamtakong Watershed (LTKW), as well as to simulate three scenarios: 1) Current land use conditions in 2021, 2) Forecasting predicted land-use changes in 2024, and 3) Water drainage regulation of the Lamtakong Reservoir (LTKR) for water resource management in 2024. The Soil and Water Assessment Tool (SWAT) model and Geographic Information System (GIS) program were used to estimate and simulate the amount of Surface Runoff (S), Sediment Yield (SED), Carbonaceous Biochemical Oxygen Demand concentration (CBOD), and Nitrate concentration (NO3) based on a comparison of simulated and observed data. In scenario 1, the S, SED, CBOD, and NO3 were calculated to be 238.44 million cubic meters (MCM), 840,613.68 tons per year, 2.38 mg/L, and 7.36 mg/L, respectively. In the second scenario, the S decreased to 14.75 MCM, whereas SED, CBOD, and NO3 increased to 56,757.48 tons, 0.56 mg/L, and 0.79 mg/L, respectively, when compared to scenario 1, (Scenario 2). Scenario 3 demonstrated that during the dry season of November to June, the standards of surface water were CBOD and NO3, and that increasing LTKR drainage can help prevent the deterioration of water yields. As a result, the HDD-M, which includes the reservoir's controlling water drainage, may need to be considered to satisfy water resource management goals.

Keywords: hydrodynamic model, reservoir, water resources management, watershed

INTRODUCTION

Human activities such as population pressure, resettlement programs, and other human-induced driving forces at the expense of land demand are strongly linked to environmental changes and obstacles to sustainable development (Regasa et al., 2021). The most important prerequisite for human life on the planet is adequate water resources. In fact, water resources are becoming increasingly important for human consumption as both population and economic expansion continue. Non-point source pollution is currently affecting the world's surface water, with agricultural non-point source pollution contributing the most (Wang et al., 2019). Non-point source pollution is now more prevalent than point source pollution and is the leading cause of surface water pollution (Li et al., 2019; Xianqi et al., 2022). Water is a key aspect of basic economic growth because it is a natural resource that is required for everything. One of the most important environmental effects of the watershed and highland protection is the hydrological impact (Zhang et al., 2020). Thailand has been experiencing water quality issues, primarily as a result of rising population, community growth, and agricultural operations along rivers' riparian zones, which includes people's homes and a rapidly growing resident population. Water quality issues and pollutant contamination are the results of such factors. Furthermore, the use of various resources, particularly water resources, to meet the current and increasing demands, if done without planning or with recklessness in the use of limited water resources, may have an impact on water yields in terms of quantity, quality, and flow timing, resulting in water pollution and degradation of water resources (Bekele, 2019; Wang et al., 2021). On all-time and spatial scales, fluctuations in land use and land cover (LULC) are the primary anthropogenic drivers of ecological change (Lambin et al., 2003; Naschen et al., 2019). For the residents of Nakhonratchasima Province, the LTKW is essential. The current water quality issues and pollution contamination entering the stream are likely to worsen and intensify, especially during the dry season flow, causing wastewater concentrations to exceed carrying capacity and affecting water yields for people and other creatures living along the river and in surrounding areas.

The goal of this research is to develop, using HDD-M, a representative watershed by regulating water drainage, simulating hydrological processes, and managing water resources in the LTKW. As a result, the research can aid in the prevention of water yield problems affecting life, ecology, and the environment, and the model can be used to develop necessary planning guidelines for limited water resources, such as planning for sustainable watershed management using systematic and sustainable concepts.

LITERATURE REVIEW

All life depends on the creation of a hydrodynamic model for water resource management in the watershed. The problem of declining water quality is mostly caused by human activities as land demand rises in tandem with population growth, and is expected to worsen further in future decades due to the impact of a growing population. By way of example, domestic sewage is one of the major sources of pollution in a watershed (Banchongsak et al., 2022; Xianqi et al., 2022). Models of hydrology and water quality are commonly used to identify and assess crucial source locations and have become increasingly popular in recent years (Narayan et al., 2021; Yuan et al., 2020).

The Soil and Water Assessment Tool (SWAT) model is one of the most commonly used hydrological and physically based models applied at the watershed scale for land use at a watershed size to partition total discharge into separate flow components (Aidi et al., 2021; Fu et al., 2019; Hu et al., 2021; Narayan et al., 2021; Shegaw et al., 2022; Tan et al., 2019). Approximately 4,000 academic papers on the SWAT model were published in peer-reviewed journals from 2001 to 2020 (Qiaoying & Dejian, 2021). The SWAT model divides the watershed into sub-watersheds, each of which is further divided into several Hydrological Response Units (HRUs), areas of land that are homogeneous and have similar responses to meteorological inputs. Each HRU is a combination of a specific land use, soil group, and slope class. The hydrological part of the model simulates a watershed's hydrologic cycle based on the water balance, and calculates the runoff, sediment, nutrients, and pesticides from each HRU. Human activities, unfortunately, have had a negative effect on water yields due to a lack of proper soil and water management practices. As a result, for long-term water resource management, considerable attention to the watershed is required.

MATERIALS AND METHODS

Study site

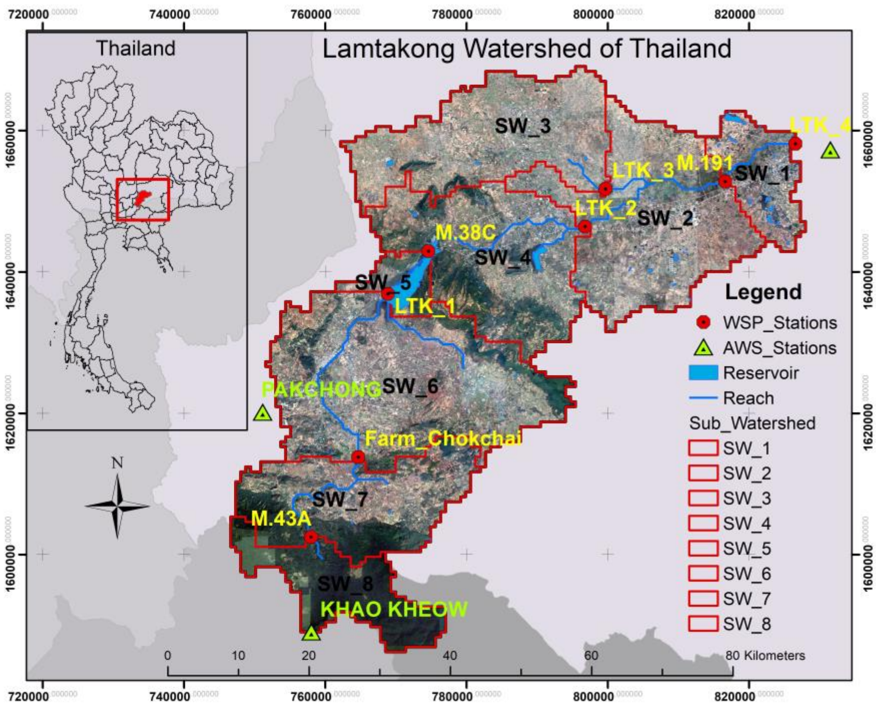
There are 16 soil groups and 14 land use types in Thailand's classification system (see Figure 1), and the key data for this study (Table 1). The Lamtakong Watershed (LTKW) is past of the Moon Watershed, which is a main watershed in Northeast Thailand, covering an area of 3,100.41 Km^2, 11 districts, 3 provinces, 3 automatic weather stations, and 8 monitoring stations; it is divided into 8 Sub-Watershed (SW). The LTKR, located in SW_5, has a maximum water storage capacity of 314.49 MCM. The first is the evergreen forest in the southwest of LTKW, which is a rural watershed with the cultivation of field crops as the major activity. The geography is flat, with heights ranging from 190 to 1,340 meters above mean sea level, with an average precipitation of 1,225 millimeters.

The Soil and Water Assessment Tool (SWAT) model

A model is an effective tool for various aspects of hydrology since it simulates finished hydrological processes at a high resolution (Gao et al., 2021; Luo & Zuo, 2019). The SWAT model was used to split the watershed into Sub-Watersheds (SW) connected with streams, and then further delineate the watershed into hydrological response units (HRUs) within each SW, taking into account the various land use, soil, and slope combinations. Hydrological processes were estimated and simulated using the model. The SWAT model is a semi-distributed, watershed scale model designed to quantify the impact of land management practices on water, nutrients, sediment, and pesticide yields in large, complex watersheds over long periods (Arnold et al., 2013; Neitsch et al., 2011).

Figure 1

Location of the LTKW Showing Major Tributaries, LTKR, 8 SW, 3 Automatic Weather Stations, and 8 Monitoring Stations



Many model comparison and review studies also suggested the SWAT model as the right choice for hydrology and pollution modeling (Fu et al., 2019; Tan et al., 2020). Land management, soil group, hydrology, weather, sediments, nutrients, pesticides, and plant and crop growth are the main model components. Thus, the SWAT model's comprehensive framework can appropriately assist in the consideration of main hydrological processes throughout a watershed. To simulate processes such as streamflow, surface runoff, sediment transport, nutrient cycling, crop growth, and water resources management, the SWAT model requires explicit information about weather, topography, the river network, vegetation, soil properties, physical and chemical properties, plants and plant growth, fertilizer, hydrology, water quality, and land management practices (Lai et al., 2020; Narayan et al., 2021; Neitsch et al., 2004) At the watershed scale, the model has been used to explore the effects of land use management, environmental changes, climate change, and human-induced ecosystem disturbances on surface runoff, sediment and nutrient yields, and water quality (Banchongsak et al., 2017; Dai & Cui, 2019; Hu et al., 2021; Merwade et al., 2017; Sun et al., 2020; Tan et al., 2019; Wang et al., 2020; Zhang, 2018).

Different running platforms of SWAT AvSWAT, ArcSWAT, and ArcSWAT were used in this study. Details on the mechanisms of SWAT can be found in the theoretical documentation (Neitsch et al., 2011). Details about the input and output files of the model can be found in the input/output documentation (Arnold et al., 2013).

Analysis and Evaluation

1. The data analysis and evaluation process was divided into 2 parts (see Figure 2), as follows: Data on average monthly Surface Runoff (S), Sediment Yield (SED), Carbonaceous Biochemical Oxygen Demand concentration (CBOD), and Nitrate concentration (NO_3) in the Lamtakong Watershed (LTKW) from each monitoring station were evaluated from January 2021 to December 2021 to use a database in the calibration/verification of the assessment by the SWAT model and ArcGIS program.

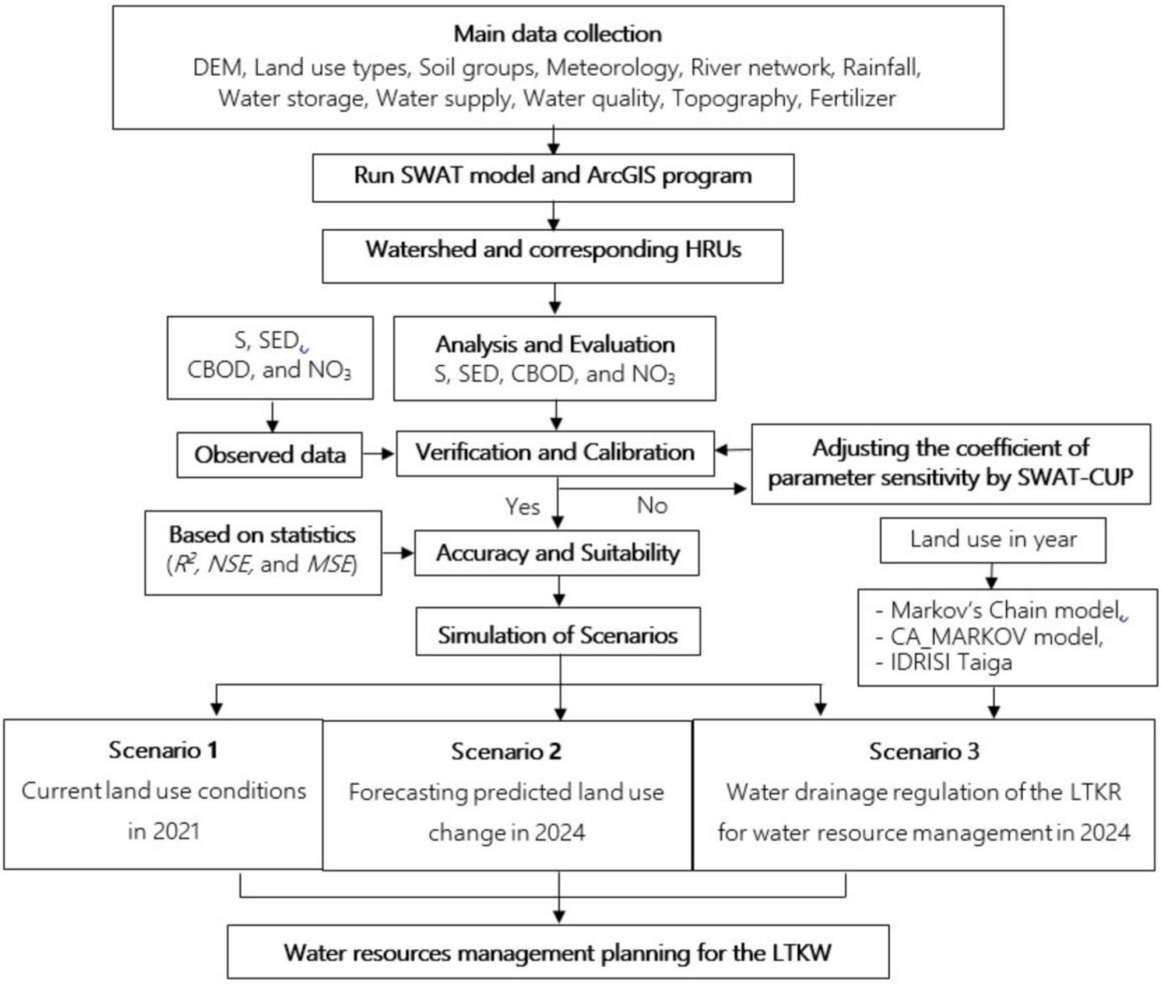
Table 1

Shows the Key Data for This Study as well as the Data Sources

Order	Data	Description/Data types	Source
1	Digital Elevation Model (DEM)	30 m	NASA and the Ministry of Economy
2	Land use types	In the years 2018, 2021	Land Development Department
3	Soil groups	Soil data of Thailand	Land Development Department
4	Meteorology	Daily	Thai Meteorological Department
5	Rainfall	Daily	Thai Meteorological Department
6	Water storage and water supply	Monthly	Royal Irrigation Department
7	Surface runoff	Monthly	Royal Irrigation Department
8	S, SED, CBOD, and NO_3	Monthly	Observed data

Figure 2

Conceptual Modeling Framework



2. The SWAT model assumes that a watershed's hydrological processes can be divided into two major divisions. The first division is the land phase of the hydrologic cycle, and the second division is its water or routing phase (Neitsch et al., 2011). The land phase of the hydrologic cycle is based on the water balance element of a watershed, as in Eq. (1).

$$SW_t = SW_0 + \sum (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \quad (1)$$

In Equation (1), SW_t is the final soil water content (mm), SW_0 is the initial soil water content (mm), t is the time (days), R_{day} is the amount of precipitation on the day (mm), Q_{surf} is the amount of surface runoff on the day (mm), E_a is the amount of evapotranspiration on the day (mm), W_{seep} is the amount of percolation and bypass flow exiting the soil profile bottom on the day (mm), and Q_{gw} is the amount of return flow on the day (mm). The current study uses S as a calibration variable, and the parameters which are significant for streamflow generation are considered for calibration. The parameter Curve Number, CN_2 is directly related to the surface runoff generation process (Rajat, 2021). The erosion and sediment yields are estimated for each HRU with Modified Universal Soil Loss Equation (MUSLE) (Williams, 1995), as in Eq. (2).

$$sed = 11.8\ (Q_{surf}\ .\ q_{peak}\ .\ area_{hru})0.56\ k_{usle}\ .\ c_{usle}\ .\ P_{usle}\ .\ LS_{usle}\ .\ CFRG \quad (2)$$

In Equation (2), sed is the sediment yield on a given day (metric tons), Q_{surf} is the surface runoff volume (mm H2O/ha), q_{peak} is the peak runoff rate (m3/s), $area_{hru}$ is the area of the HRUs, k_{usle} is the USLE soil erodibility factor (0.013 metric ton m2 hr/(m3 -metric ton cm), c_{usle} is the USLE cover and management factor, P_{usle} is the USLE support practice factor, LS_{usle} is the USLE topographic factor, and CFRG is the coarse fragment factor.

The CBOD defines the amount of oxygen required to decompose the organic matter transported in surface runoff and is based on a relationship (Thomann & Mueller, 1987), as in Eq. (3).

$$cbod_{surq} = \cdot \frac{2.7 \cdot orgC_{surq}}{Q_{surf} \cdot area_{hru}} \quad (3)$$

In Equation (3), $cbod_{surq}$ is the CBOD concentration surface runoff (mg CBOD/L), $orgC_{surq}$ is the organic carbon in surface runoff (kg orgC), Q_{surf} is the surface runoff on a given day (mm H2O), and $area_{hru}$ is the area of the HRUs (km^2).

Once the nutrient load in surface runoff and lateral flow is determined, the amount of nutrients released to the main channel is calculated, as in Eq. (4).

$$NO3_{surf} = \left(NO3'_{surf} + NO3_{serstor,i-1}\right) \cdot \left(1 - exp\left[\frac{-surlag}{t_{conc}}\right]\right) \quad (4)$$

In Equation (4), $NO3_{surf}$ is the amount of nitrate discharged to the main channel in a surface runoff on a given day (kg N/ha), $NO3'_{surf}$ is the amount of surface runoff nitrate generated in an HRU on a given day (kg N/ha), $NO3_{serstor,i-1}$ is the surface runoff nitrate stored or lagged from the previous day (kg N/ha),$-surlag$ is surface runoff lag coefficient, and t_{conc} is the time of concentration for the HRUs (hrs).

Calibration and Verification

The Soil and Water Assessment Tool (SWAT) model simulation results were calibrated and validated using observed data for Surface Runoff (S), Sediment Yield (SED), Carbonaceous Biochemical Oxygen Demand concentration (CBOD), and Nitrate concentration (NO_3) from eight monitoring stations from January to December 2021, as well as sensitivity analysis for the SWAT-CUP model (Abbaspour, 2015; Abbaspour et al., 2014; Baeza & Garcia, 2005; Karakoyun et al., 2018; SWATPubDatabase, 2020). Analysis of correlation efficiency and appropriateness of the SWAT model relied on the use of the Coefficient of Determination (R^2), Nash-Sutcliffe efficiency coefficient (NSE), and Mean Squared Error (MSE).

$$NO3_{surf} = \left(NO3'_{surf} + NO3_{serstor,i-1}\right) \cdot \left(1 - exp\left[\frac{-surlag}{t_{conc}}\right]\right)$$

Simulation of land utilization activities affecting the Surface Runoff (S), Sediment Yield (SED), Carbonaceous Biochemical Oxygen Demand concentration (CBOD), and Nitrate concentration (NO_3)

Following model calibration and verification, the model was used to assess the influence of land use activities on S, SED, CBOD, and NO_3. These calibrated parameters were used in the following three scenarios:

- **Scenario 1**: The current state of land use in 2021, with normal water drained from the LTKR affecting the S, SED, CBOD, and NO_3.
- **Scenario 2**: Land use in the LTKW is predicted to undergo change in 2024, and normal water drained from the LTKR in SW 5 has an impact on S, SED, CBOD, and NO_3. The land use database for the years 2018 and 2021 was used to forecast the future land use changes. The Cellular Automata-Markov (CA-Markov) model was used in this investigation (Guan et al., 2011; Mohamed et al., 2022; Ross, 2010; Sinha

& Kimar, 2013; Varga et al., 2019) along with IDRISI Taiga (Eastman, 2009; Li et al., 2015; Rutherford et al., 2007; Wang et al., 2012), which predicts LULC change by including a geographical distribution factor. Land use mapping for the year 2024 was also developed.

- **Scenario 3**: The consequences of land use change in the year 2024, were simulated with normal and projected water drainage from the LTKR influencing CBOD and NO_3.

The SWAT model and ArcGIS application were used to develop HDD-M, which was then used to analyze the S, SED, CBOD, and NO_3 that could occur in each scenario. The findings were used in the LTKR's water resource management planning and water drainage regulation for people and all other creatures living along the river, in neighboring areas.

RESULTS AND DISCUSSION

The hydrological response units (HRUs) of the Lamtakong Watershed (LTKW)

Using the Digital Elevation Model (DEM) 30 x 30 meters to calculate the slope, flow direction, SW, and outflows point, the HRUs in the LTKW corresponding to the fraction of land use categories in the year 2021, soil groups, and slope class of the LTKW were determined. With respect to percentages, 5% for land use types, 10% for soil groups, and 10% for slope class were employed. Each SW is separated into several HRUs based on the DEM, LULC, slope class, and soil properties (Ayivi & Jha, 2018). In total, the area is divided and subdivided into 8 SWs and 115 HRUs. Each HRU was first subjected to a SWAT model hydrological examination. Based on physical formulas explaining the complex S creation and confluence processes, the created S was then converged to the outlets of SW, and, eventually, to the outflow of the LTKW area (see Figure 3).

The calibrated Soil and Water Assessment Tool (SWAT) parameter sensitivity of the Lamtakong Watershed (LTKW)

The SWAT model's calibrated parameter sensitivity was used to show uncertainty and the necessary adjustment coefficient for various parameters (Table 2).

The calibration of the Surface Runoff (S), Sediment Yield (SED), Carbonaceous Biochemical Oxygen Demand concentration (CBOD), and Nitrate concentration (NO_3) of the Lamtakong Watershed (LTKW)

The calibration of the SWAT model using the analyzed sensitivity in the form of R^2, NSE, and MSE (Shegaw et al., 2022) starts from the calibration of the upper SW to the sequential lower SW. The first calibration parameter was the S, SED, CBOD, and NO_3, respectively. The 8 monitoring stations within the LTKW, including M.43A, Chokchai Farm, LTK_1, M.38C, LTK_2, LTK_3, M.191, and LTK_4, were employed for calibration (Table 3).

Figure 3

The HRUs of Land Use Types (a); Soil Groups (b); and Slope Class (c)

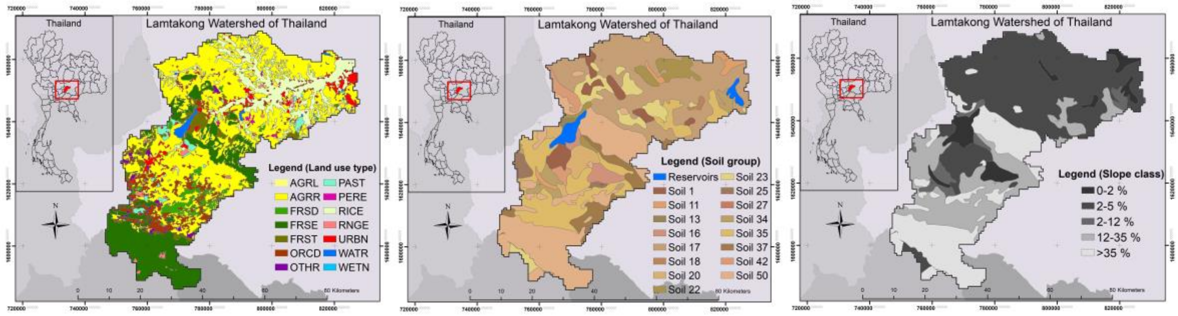


Table 2

The LTKW is Calibrated SWAT Parameter Sensitivity

Parameter calibration	Parameter name	Definition/Parameter in SWAT model to be adjusted	Input file	Calibrated value
Parameters calibrated for S	ALPHA_BF	Base flow alpha factor.	.gw	0.241
	SOL_AWC	Available water capacity of the soil layer.	.sol	0.678
	CH_K(2)	Effective hydraulic conductivity in the main channel.	.rte	162.433
	CH_N(2)	Manning's "n" value for the main channel.	.rte	0.051
	ESCO	Soil evaporation compensation factor.	.bsn, .hru	0.956 0.921
	CANMX	Maximum canopy storage.	.hru	37.086
	BLAI	Maximum potential leaf area index.	crop.dat	1.457
	CN2	Initial SCS runoff curve number for moisture condition 2.	.mgt	65.482
Parameters calibrated for SED	SPCON	The coefficient in the sediment transport equation.	.bsn	0.006
	SPEXP	The exponent in the sediment transport equation.	.bsn	1.358
	PRF	Peak rate adjustment factor for sediment routing.	.bsn	1.245
	CH_COV	Channel cover factor.	.rte	0.861
	CH_EROD	Indicates resistance to erosion.	.hru	0.576
	USLE_P	USLE equation support practice factor.	.mgt	0.826

Table 2 (Continued)

Parameter calibration	Parameter name	Definition/Parameter in SWAT model to be adjusted	Input file	Calibrated value
Parameters calibrated for SED	USLE_C	The minimum value for the cover and management factor for the land cover/plant.	Crop.dat	0.645
	SLSUBBSN	Average slope length.	.hru	50.000
Parameters calibrated for CBOD concentration	SOL_CBN	Organic carbon content in the layer.	.sol	3.982
	BIO_BD	The density of biomass.	.sep	1,002.314
	COEFF_CBOD_DC	CBOD decay rate coefficient.	.sep	1.899
	COEFF_MRT	Mortality rate coefficient.	.sep	0.334
	COEFF_RSP	Respiration rate coefficient.	.sep	0.465
	COEFF_CBOD_CONV	A conversion factor represents the proportion of mass bacterial growth and mass CBOD degraded in the STE.	.sep	0.253
Parameters calibrated for NO_3 concentration	ANION_EXCL	Fraction of porosity from which anions are excluded.	.sol	0.521
	NPERCO	Nitrate percolation coefficient.	.bsn	0.258
	SURLAG	Surface runoff lag coefficient.	.bsn	4.741
	LAT_TTIME	Lateral flow travel time.	.hru	0.539

Table 3

The Correlation Efficiency of the S, SED, CBOD, and NO_3 of the LTKW Based on the R^2, NSE, and MSE

Main parameter	Station code	R^2	NSE	MSE	Period of observed data
S	M.43A	0.97	0.85	5.74	January – December In the year 2021
	Farm_Chokchai	0.97	0.87	8.66	
	LTK_1	0.96	0.81	-7.52	
	M.38C	0.87	0.57	13.38	
	LTK_2	0.90	0.79	8.12	
	LTK_3	0.84	0.68	15.65	
	M.191	0.87	0.73	13.91	
	LTK_4	0.98	0.93	3.44	
SED	M.43A	0.97	0.93	7.24	January – December In the year 2021
	Farm_Chokchai	0.90	0.71	12.30	

Table 3 (Continued)

Main parameter	Station code	R^2	NSE	MSE	Period of observed data
SED	LTK_1	0.61	0.64	-2.55	
	M.38C	0.90	0.61	24.21	
	LTK_2	0.83	0.82	8.85	
	LTK_3	0.89	0.89	13.65	
	M.191	0.62	0.57	-6.97	
	LTK_4	0.87	0.77	5.54	
CBOD	LTK_2	0.78	0.79	3.21	January – December in the year 2021
	M.191	0.74	0.62	-12.96	
	LTK_4	0.83	0.81	4.88	
NO_3	LTK_2	0.73	0.68	7.02	January – December in the year 2021
	M.191	0.70	0.77	-8.74	
	LTK_4	0.85	0.83	3.61	

The results of the predicted the Surface Runoff (S), Sediment Yield (SED), Carbonaceous Biochemical Oxygen Demand concentration (CBOD), and Nitrate concentration (NO_3) of the Lamtakong Watershed (LTKW)

The following are the outcomes of the HDD-M for water resources management from LTKR with respect to S, SED, CBOD, and NO_3 under the three different scenarios:

Scenario 1: Current land use in 2021 under typical water drainage conditions.

On the LTKW, the model has proven to be beneficial in simulating hydrological processes. The SWAT model was calibrated and verified in our study utilizing S, SED, CBOD, and NO_3 data collected before the LTKW water resource management planning. The overall amount of S from the LTKW was 238.44 MCM, with the maximum monthly value of 70.33 MCM at SW 2 in October due to cumulative rainfall and soil water content during the rainy season, and the lowest monthly value of 0.14 MCM at SW 6 in January due to the effects of the dry season. Because the LTKW's main activity is field crops, the total amount of SED produced per year was 840,613.68 tons, with the highest monthly value at SW 1 in September being 196,352.14 tons and the lowest monthly value at SW 3 in April being 1,865.94 tons. Plains are scarce and concentrated in the downstream areas, and agricultural activities have an impact on water quality (Perez-Sanchez et al., 2020). Because the amount of CBOD was diluted by high water discharge, the average CBOD from the LTKW was 2.38 mg/L, with the highest average monthly value of 4.95 mg/L at SW 1 in December and the lowest average monthly value of 0.61 mg/L at SW 4 in September. Because the amount of NO_3 was diluted by high rainfall, the average NO_3 from the LTKW was 7.36 mg/L, with the highest average monthly value at SW 2 in December up to 17.69 mg/L and the lowest average monthly value at SW 1 in August being 3.14 mg/L (see Figure 4).

Scenario 2: **The land use change within the LTKW is forecasted to occur in 2024, with normal water drained from the LTKR in SW 5 influencing the S, SED, CBOD, and NO_3.**

The findings of this study revealed that when the land use ratio changed from Scenario 1 to Scenario 2, the total amount of S from the LTKW was 223.69 MCM, down 14.75 MCM. SW 2 had the highest monthly value of 60.21 MCM in October, and SW 7 had the lowest monthly value of 0.14 MCM in January because the forest area decreased and the maximum discharge increased. The runoff reflects the watershed's hydrological processes, which are heavily impacted by climate and the underlying surface (Huo et al., 2016; Luo et al., 2020). The total amount of SED produced by the LTKW was 840,613.68 tons per year, up 56,757.48 tons over Scenario 1. Because of increased numbers of field crops and paddy fields, the maximum monthly value at SW 1 in September was 196,352.14 tons, and the lowest monthly value at SW 3 in February was 1,654.01 tons. Because of the extensive use of water and soil agriculture activities, humans have had a substantial impact on the watershed (Kamran et al., 2022). The LTKW's average CBOD was 2.94 mg/L, with the greatest average monthly value of 4.85 mg/L at SW 1 in April and the lowest average monthly value of 0.65 mg/L at SW 2 and SW 4 in September and August, respectively. Because of the increasing use of pesticides, the total amount of NO_3 from the LTKW was 8.15 mg/L, with the greatest average monthly value of 17.54 mg/L at SW 2 in March and the lowest average monthly value of 3.54 mg/L at SW 1 in July. There were residues on plants, soil surfaces, and in rivers as a result (see Figure 5), and the land use change ratio of the LTKW in Scenario 2 (Table 4).

Figure 4

Monthly Comparison of Aactual and Simulated Surface Runoff (a), Sediment Yield (b), Carbonaceous Biochemical Oxygen Demand Concentration (c), and Nitrate Concentration (d) During the Calibration Phase of the LTKW From January to December 2021, (Scenario 1)

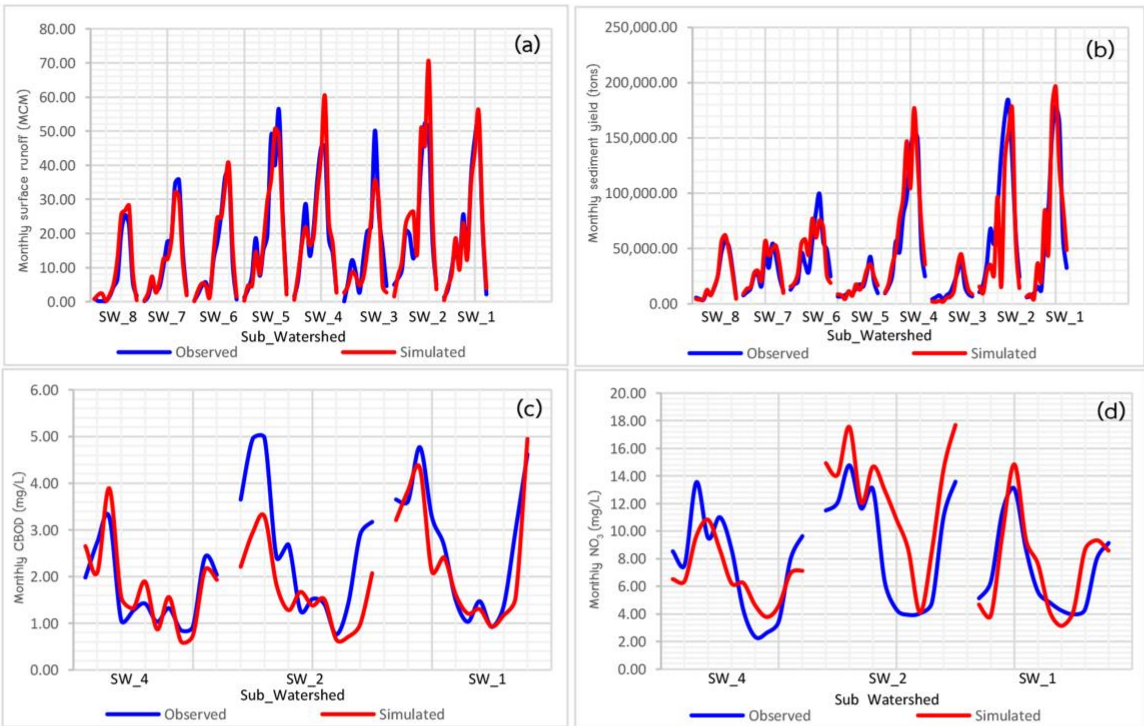
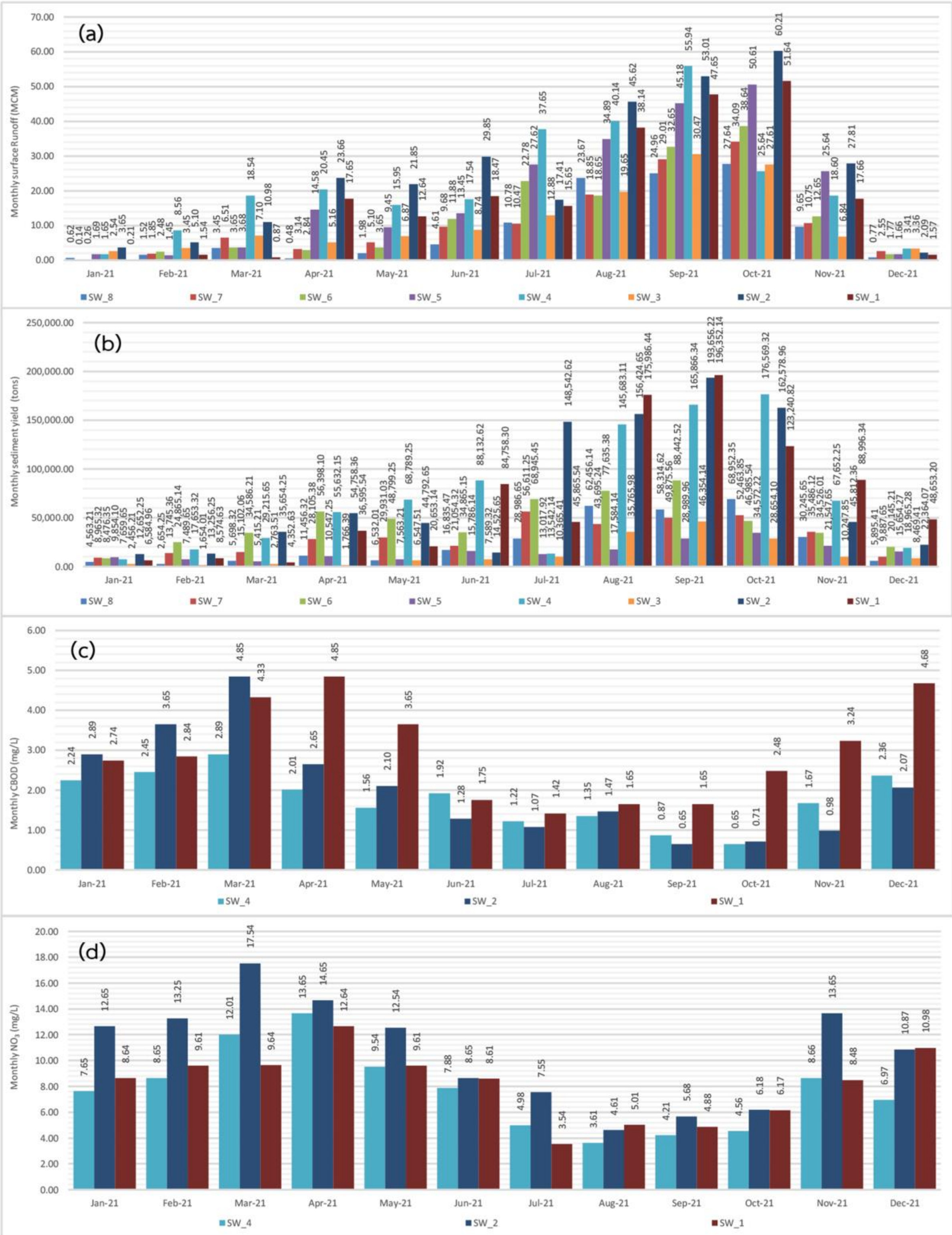


Figure 5

The Results of the Surface Runoff (a); Sediment Yield (b); Carbonaceous Biochemical Oxygen Demand Concentration (c); and Nitrate Concentration (d) in Each SW of the LTKW (Scenario 2)



Scenario 3: Water drainage in the LTKR is regulated within SW 5 for LTKW water resource management in 2024 (see Figure 6).

The impacts of normal and proposed water drainage from the LTKR on CBOD and NO_3 in downstream locations (SW 4, SW 2, and SW 1) were simulated. CBOD and NO_3 readings were recorded in the form of a monthly comparisons of normal and proposed water drainage to fulfill the surface water criterion of class 2 for aquaculture conservation (CBOD < 1.5 mg/L, NO_3 < 5 mg/L) (see Figure 7 and Table 5). During the wet season, CBOD and NO_3 in the main channel or reach were low because pollution from both point and non-point sources are more common after heavy rains. While there is little rain during the dry season, there is a tiny amount of runoff, and the source of pollution in human settlements is rural home sewage, resulting in high CBOD and NO_3. The surface soil's propensity to compress could be attributed to the rise in agricultural operations. Overall, changes in land cover have a significant impact on water yields (Aidi et al., 2021).

Table 4

The Land Use Change Ratio of the LTKW in the Year 2021 (Scenario 1), and in the Year 2024 (Scenario 2)

Order	Land use types	Scenario 1		Scenario 2		Land use change	
		km^2	%	km^2	%	km^2	%
1	Agricultural Land (AGRL)	2.11	0.07	3.69	0.12	1.58	0.05
2	Field Crops (AGRR)	1417.02	45.70	1481.65	47.79	64.63	2.08
3	Deciduous Forest (FRSD)	93.33	3.01	80.14	2.58	-13.19	-0.43
4	Evergreen Forest (FRSE)	566.44	18.27	557.32	17.98	-9.12	-0.29
5	Forest Plantation (FRST)	104.36	3.37	85.41	2.75	-18.95	-0.61
6	Orchards (ORCD)	194.89	6.29	197.65	6.37	2.76	0.09
7	Others (OTHR)	36.70	1.18	15.65	0.50	-21.05	-0.68
8	Pasture and Farmhouse (PAST)	55.04	1.78	32.87	1.06	-22.17	-0.71
9	Perennial (PERE)	10.92	0.35	6.58	0.21	-4.34	-0.14
10	Paddy Field (RICE)	441.93	14.25	468.65	15.12	26.72	0.86
11	Rangeland (PNGE)	29.40	0.95	20.64	0.67	-8.76	-0.28
12	Urban and Built-up Land (URBN)	117.78	3.80	119.65	3.86	1.87	0.06
13	Water (WATR)	29.60	0.95	29.60	0.95	0.00	0.00
14	Wetland (WETN)	0.90	0.03	0.90	0.03	0.00	0.00
Total		3100.41	100.00	3100.41	100.00	-	-

Figure 6

Projected Land Use of LTKW, LTKR, and SW_1 to SW_8 in the Year 2024

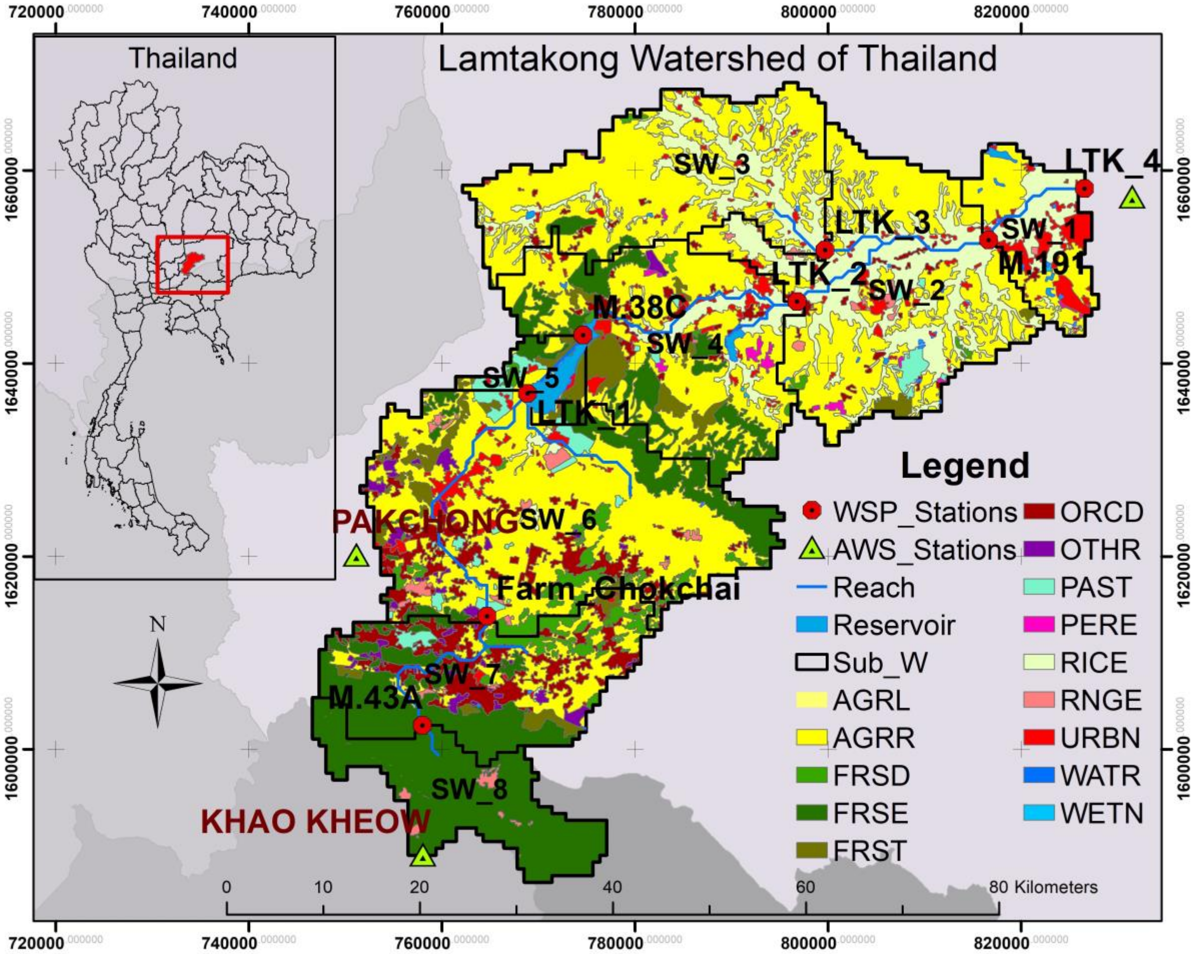


Figure 7

The Normal and Proposed Water Drainage From the LTKR and Rainfall Data

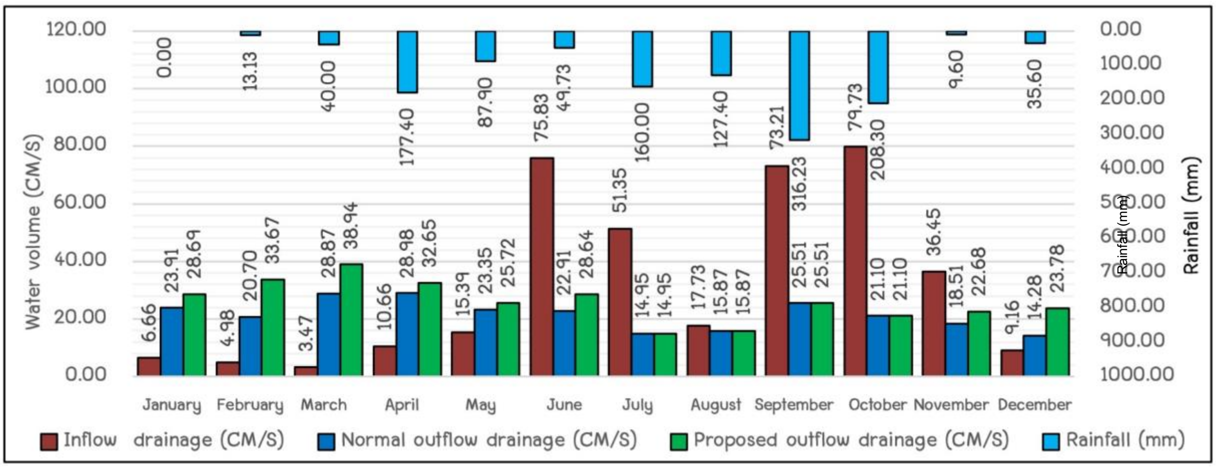


Table 5

The CBOD and NO_3 Derived From Normal and Proposed Water Drainage of the LTKR

Period	Normal water drainage of the LTKR						Proposed water drainage of the LTKR					
	SW_4 (LTK-2)		SW_2 (M.191)		SW_1 (LTK-4)		SW_4 (LTK-2)		SW_2 (M.191)		SW_1 (LTK-4)	
	CBOD (mg/L)	NO_3 (mg/L)	CBOD (mg/L)	NO_3 (mg/L)	CBOD (mg/L)	NO_3 (mg/L)	CBOD (mg/L)	NO_3 (mg/L)	CBOD (mg/L)	NO_3 (mg/L)	CBOD (mg/L)	NO_3 (mg/L)
Jan	2.24	7.65	2.89	12.65	2.74	8.64	1.50	4.87	2.47	8.41	2.63	5.10
Feb	2.45	8.65	3.65	13.25	2.84	9.61	1.50	4.17	3.02	7.64	2.41	5.99
Mar	2.89	12.01	4.85	17.54	4.33	9.64	1.50	4.65	3.64	10.56	3.21	7.81
Apr	2.01	13.65	2.65	14.65	4.85	12.64	1.50	4.02	2.36	9.61	3.85	10.47
May	1.56	9.54	2.10	12.54	3.65	9.61	1.50	4.73	1.87	11.24	2.22	6.45
Jun	1.92	7.88	1.28	8.65	1.75	8.61	1.50	3.14	1.18	4.76	1.39	6.27
Jul	1.22	4.98	1.07	7.55	1.42	3.54	1.02	4.05	1.01	3.91	1.12	4.62
Aug	1.35	3.61	1.47	4.61	1.65	5.01	1.25	2.23	1.30	3.28	1.40	4.85
Sep	0.87	4.21	0.65	5.68	1.65	4.88	0.81	2.42	0.57	3.77	0.85	3.23
Oct	0.65	4.56	0.71	6.18	2.48	6.17	0.62	3.03	0.68	3.04	1.09	4.66
Nov	1.67	8.66	0.98	13.65	3.24	8.48	1.50	4.78	0.74	4.76	1.49	6.85
Dec	2.36	6.97	2.07	10.87	4.68	10.98	1.50	4.82	1.91	10.08	3.34	7.66
Avg.	1.77	7.70	2.03	10.65	2.94	8.15	1.31	3.91	1.73	6.76	2.08	6.16

Note. The surface water criterion of class 2 for aquaculture conservation: CBOD < 1.5 mg/L, NO_3 < 5 mg/L. Adapted *from Enhancement and conservation of national environmental quality ACT, B.E. 1992, Water quality monitoring of surface water sources documentation, Under freshwater resources* (pp. 234-240), by Pollution Control Department, Ministry of Natural Resources, 2535, Academic Press. Copyright 2535, by Ministry of Natural Resources.

CONCLUSIONS

In this study, the SWAT model and the ArcGIS application were used to simulate three scenarios in the LTKW of Thailand. The model's verification results are highly accurate and successful in the SW and key watersheds. Some land use modifications, such as converting pasture and farmhouses, as well as deciduous forest to field crops, paddy fields, and orchards, may be required in conjunction with these scenarios, which could have an impact on the ecology and environment. The findings of the simulations reveal that land use patterns and reservoir water drainage have an impact on S, SED, CBOD, and NO_3. The need for water will almost certainly continue to rise in the future. For people and all other creatures living in Pak Chong, Si Khiu, Sung Norn, Kham Thale So, and Muang districts and surrounding areas, the HDD-M can assist policymakers and scientists with a rapid preliminary assessment of hydrological processes and environmental science, as well as an approach to managing water to reduce water loss and regulate water drainage. As a result, the HDD-M, which comprises the regulating water drainage of the reservoir, may need to be considered to meet water resource management goals. As a result, decision-makers and stakeholders should establish plans to promote better land use management techniques to achieve balanced and long-term ecological strategies.

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