Journal of Applied and Natural Science
14(3), 1039 - 1050 (2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Effects of land-use change on the volume of water flow into the Mun Bon reservoir in Nakhon Ratchasima Province, Thailand

Surachat Sinworn
Science and Technology, Suan Dusit University, Bangkok, Thailand
Nuttabodee Viriyawattana*
Science and Technology, Suan Dusit University, Bangkok, Thailand

*Corresponding author. Email: nutta_v@hotmail.com

Article Info
https://doi.org/10.31018/jans.v14i3.3690
Received: July 7, 2022
Revised: September 3, 2022
Accepted: September 8, 2022

How to Cite

Sinworn, S. and Viriyawattana, N. (2022). Effects of land-use change on the volume of water flow into the Mun Bon reservoir in Nakhon Ratchasima Province, Thailand. *Journal of Applied and Natural Science*, 14(3), 1039 - 1050. https://doi.org/10.31018/jans.v14i3.3690

Abstract
The land-use patterns in watershed areas in the Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, Thailand, have been found to change from forest areas. Different agricultural areas cause variations in the amount of water that flows from the stream into the reservoir, potentially leading to future water shortages. This study was conducted to explore the effects of land-use change on the volume of water flow into the Mun Bon Reservoir, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, Thailand. The model analysis techniques, namely Markov's Chain CLUES and SWAT, were employed to predict the effects of land-use patterns in the area of the upper Mun River on the volume of water flow into the Mun Bon reservoir. According to the predictions obtained based on the land-use models, forest areas may be converted into cassava plantations by 2029. When the comparative effects were considered, the normal volume of water flowing into the Mun Bon reservoir was found to be equivalent to 96 million cubic meter per year. The predicted volume before Christ (A.D.) 2029 is 30 million cubic meter. Accordingly, the water volume in the Mun Bon reservoir would be lower than that derived from the usual land-use patterns.

Keywords: Land use, Mun Bon reservoir, Nakhon Ratchasima, Waterflow

INTRODUCTION

The Mun River is located in northeastern Thailand and is one of the largest branches of the Mekong River. This river lies between latitude 14° and 16° and longitude 101° 30' and 105°30', with a length and basin area of approximately 800 km and 71,060 km^2, respectively (Meyer *et al.*, 2019; Chotpantarat and Boonkaewans, 2018). Individuals that earn money through agricultural activities and reside in the area of flow of the Mun River and river branch usually rely on the water from the river and river branches for farming and agricultural purposes. This reliance is particularly true for Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, which is the area in the upper part of the Mun River. Water from the river flows into the Mun Bon reservoir, a medium-sized reservoir that can store up to 122.63 million cubic meter water volume. Mun Bon reservoir supplies water for 72.23 square kilometers of irrigation areas covering four districts, namely Khon Buri, Chokchai, Muang Nakhon Ratchasima, and Chalermprakiat in Nakhon Ratchasima province in northeastern Thailand. In the drought season, when no rainfall occurs to nurture agricultural produce, the Mun River and river branches that flow into the Mun Bon reservoir are considered important for these agricultural areas. Economic crops in these areas include hemp, sugarcane, and cassava (Jamshidi and Tajrisky, 2010), with cassava as the best crop in these areas in Thailand. Cassava is transferred to a processing plant as a primary material for cassava flour, pellet pet food, and ethanol. Accordingly, the trend of expanding cassava plantations has been increasing each year (Boonrawd *et al.,* 2012). In this expansion, forest areas, including natural forests and community forests, have been converted into cassava plantations (Phangam *et al.,* 2020). Such circumstances result in changes in land use at the macro level, which affects the ecological system, natural resources, and the local community economy (Phanurak and Suwanwaree, 2013). As a result, the water demand has increased following the expansion of cassava plantations. The increasing demand has resulted in a lack of water supply, competition for water in the drought season, and changes in land utilization.

Land-use changes (LUC) remarkably influence hydrological components, such as evapotranspiration, soil infiltration, subsurface water injection, surface runoff, and precipitation (Praweenwongwuthi *et al.,* 2017). Accordingly, LUC is regarded as significant information for determining water resources in water sources, including rivers (Dessu and Melesse, 2012). In the context of changes, LUC reflects dynamic changes in the study area at present and in the future. Changes in land use or LUC occur in the Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, Thailand, which is the area in the upper part of the Mun River. In fact, the volume of water flowing into the river has continuously decreased. Therefore, relevant agencies must seek information on the effects of land-use change on the water volume flowing into the reservoir from before Christ (A.D.) 2019 to A.D. 2029. The potential effects were predicted using the CA-Markov model based on the database of land-use change. Notably, the effects of water volume flowing into the reservoir can be evaluated (Gassman *et al*., 2007). Accordingly, the above model has been widely adopted, especially in water current flow simulation and dietary nutrients under the influence of changing environments, along with changes in climate and LUC at the river basin level, particularly in the Southeast Asia region (Li and Fang, 2021). However, these data can only be used for past and recent assessments. Therefore, the construction of future simulation models must rely on additional applications of the conversion of land use and its effects modeling framework (CLUEs) model. The CLUEs model is a flexible, generic land-use modeling framework that allows scale and context-specific specification for regional applications. The CLUE model has been applied worldwide in many different environments. Typical applications include the simulation of deforestation, land degradation, urbanization, land abandonment, and integrated assessment of land cover change. Accordingly, changes in LUC can be predicted in line with the geographical, economic, and social influences on each type of LUC (Harylenko *et al.,* 2016). The CLUEs model has been widely used to develop changes in future LUC situations in several regions (Dessu and Melesse, 2012; Barker and Miller, 2013; Rode *et al.,* 2009). One method of data collection is prediction based on hydrological simulation (Praweenwongwuthi *et al.,* 2017), which consistently requires physical data to predict the effects of land use on water flow and agricultural management (Dessu and Melesse, 2012; Gassman *et al.,* 2007). All data were integrated into the Soil and Water Assessment Tool (SWAT), which offers a land use simulation, considering the agricultural activities that impact the volume of water flowing into the Mun Bon reservoir (Li and Fang, 2021). By utilizing data in various dimensions, including socioeconomic aspects and the environment, to simulate the effects on the volume of water, water flow simulation can be employed as a guideline for land use that responds to the demand of the majority of the area and emphasizes the fragility of natural resource use to enable sustainable management of land use (Wang *et al*., 2016). The purpose of this study was to predict the impact of land-use change in upstream areas on the amount of water that flows into the Mun Bon Reservoir from B. E. 2019–2029 to use the data in water resource management for the community.

MATERIALS AND METHODS

Study area and land-use selection

The study area covered four zones: 14º 30' 16.23'N, 102º 6' 29.17'E (North of Mun Bon Resorvior); 14º 28' 49.79'N, 102º 4' 9.57'E (East of Mun Bon Resorvior); 14º 26' 52.52'N, 102º 2' 33.80'E (West of Mun Bon Resorvior); and 14º 24' 50.02'N, 102º 5' 39.47'E (South of Mun Bon Resorvior). The areas covered were Moo 5 of Bann Taling Chan, Moo 7 of Bann Mun Bon, Moo 9 of Bann Taling Chan (the basin through which the Mun River flows), Moo 10 of Bann Taling Chan, Moo 11 of Bann Jom Thong, and some areas in Tublan National Park, through which the Mun River and its branches flow. There were of 16 types of land-use. The total area is 63.36 square kilometers. Most of the area is forest area in Tublan National Park, with a geographical feature of complex mountain ranges and tropical rain forests. The remaining area is 0.14 square kilometers and lies outside the national park. The total population of the Chorakhe Hin sub-district is 12,248 people (Fig. 1).

The effect of land use on the volume of water flowing into the Mun Bon reservoir was conducted in an area that covered 63.36 square kilometers. The study comprised Chorakhe Hin sub-district and villages, where the Mun River and its branches flow, and included Moo 5 of Bann Taling Chan, Moo 7 of Bann Mun Bon, Moo 9 of Bann Taling Chan, Moo 10 of Bann Taling Chan, Moo 11 of Bann Jom Thong, and some areas in Tublan National Park, in which the farmers were granted rights to conduct rice farming, as outlined by the red line in Fig. 2, except the Mun Bon reservoir and the villages located behind the upper part of the reservoir. The other zones are represented by ▭ in Fig. 2.

Methodology

A land-use database was developed using a geographic information system (GIS) to calculate the area of each type of land use. The changes were analyzed using union overlay operation techniques for land-use data. Cross tabulation was then adopted in the change analysis to determine the proportion of land use that might increase or decrease (Hua *et al.,* 2015). The change matrix of land use between A.D. (Anno Domini) 2011 and A.D. 2018 was analyzed. Further, future land use was predicted, and the change matrix between A.D. 2019 and A.D. 2029 was analyzed by determining transitional areas and the probability of change in each type of land use. Data were analyzed through a CA-Markov simulation to predict the land-use patterns from A.D. 2019 to A.D. 2029. The relationship between the areas of consideration and the neighboring areas was a major factor, and Markov simulations were used to explain changes in the proportion of each type of land use. In this study, there were 16 types of land use: 1) corn, 2) paddy fields, 3) abandoned paddy fields, 4) cassava, 5) sugarcane, 6) rubber, 7) eucalyptus, 8) abandoned field, 9) mixed fruit, 10) bamboo for commercial purposes, 11) government offices and institutes, 12) community, 13) planted forest, 14) natural forest, 15) grassland alternated with shrub/grove, and 16) river source. Bayes' probability theorem was used, as illustrated in Equations 1 and 2 (Sang *et al.,* 2011). The matrix was then calculated in combination with spatial driving variables, and CA was applied to determine the spatial patterns of the lands where land-use prediction was made (Yagoub and BiZreh, 2014), as shown in Equation 1.

$$S(t+1) = P_{ij} X\, s(t) \qquad \text{Eq. 1}$$

For S(t+1), S(t) is the status at time t or t+1,
The probability matrix of change calculated from the equation

$$P_{ij}\begin{bmatrix} P_{11}\ P_{12}\ \dots P_{1n} \\ P_{21}\ P_{22}\ \dots P_{2n} \\ \dots\ \dots\ \dots \\ P_{n1}\ P_{n2}\ \dots P_{nn} \end{bmatrix} \qquad \text{Eq. 2}$$

when

$$0 \le P_{ij} < 1 \ \text{และ}\ \sum_{j=1}^{n} P_{ij} = 1(i,j = 1,2,\dots n)$$

The appropriateness of each type of land use and the eight factors affecting land use were the height from the seal level, slope, aspect, rain amount, effective soil depth, distance from water sources, distance from roads, and distance from communities. The values obtained from the regression were then used as input to the CLUE-S model. The model was tested for accuracy using the relative operating characteristic (ROC) method, in which the value must lie between 0 and 1 (Verburg *et al.,* 2002). The prediction of land-use change in B. E. 2029 relied on the CLUE-S model using the land use in the areas around the Mun River and branches flowing into the Mun Bon reservoir in the Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima in A.D. 2019 as an input; this was referred

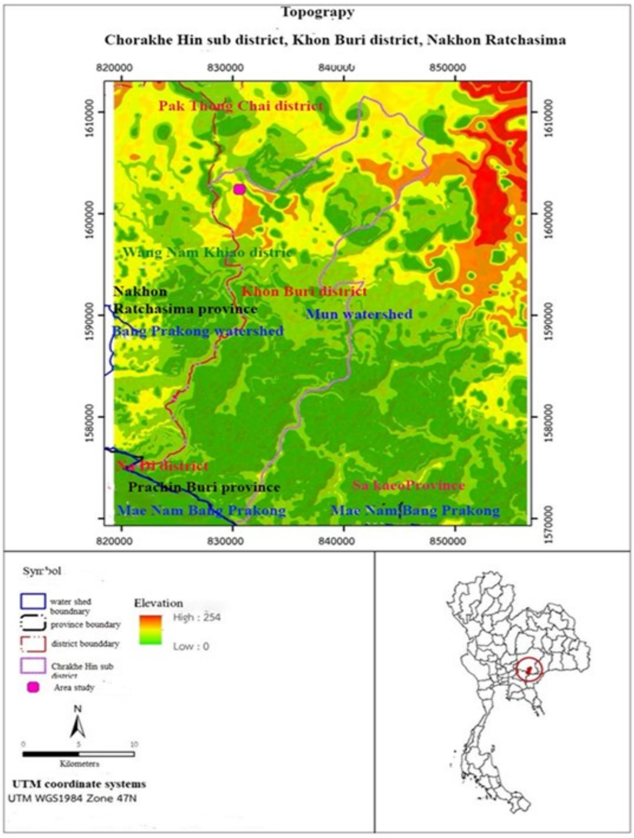

Fig. 1. *Topography of Chorakhe Hin Sub district and neighborhood*

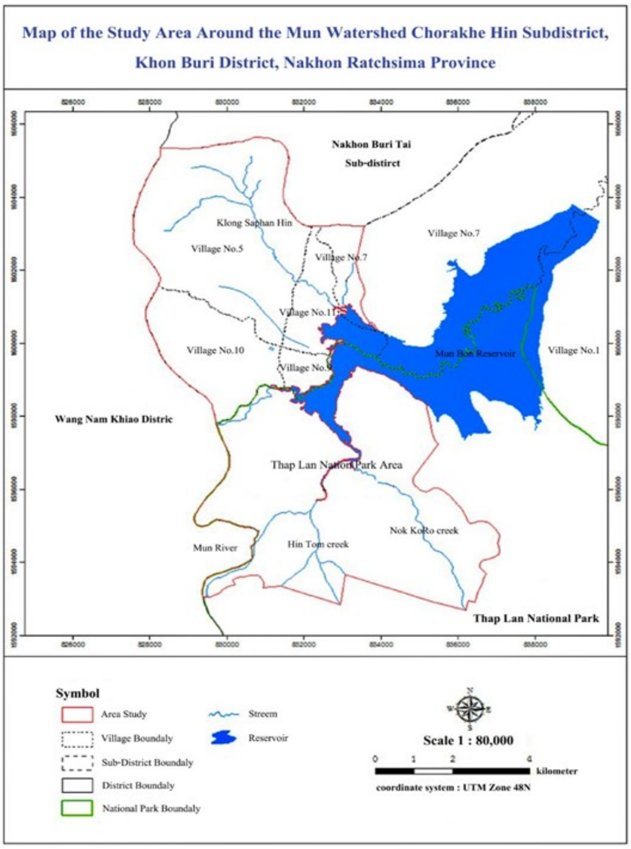

Fig. 2. *Research area boundary*

to as the initial data, along with data on land-use driving factors, coefficients from logistic regression, and data on the flexibility of land-use change. The results from the model were spatial patterns, and the land-use changes in A.D. 2029 were analyzed. The volume of water flowing into the reservoir was analyzed using the Soil and Water Assessment Tool (SWAT) model. The factors that influence the volume of water flowing into the reservoir were compiled for the model, and included the digital elevation model (DEM), land use, soil series, and climate data, such as rainfall amount, the highest and lowest temperature, relative humidity, sun ray, velocity, and volume of water flow (Hua *et al.,* 2015; Sang *et al.*, 2011; Yagoub and Bizreh, 2014), and the reservoir from the Mun Bon reservoir gauging station based on an assessment of the volume of water flowing into the reservoir at the Mun River basin and its branches. The SWAT model was applied with inputs of the DEM, land use, and soil series. Hydrological response units (HRUS) were determined based on the types of land use, soil, and soil slopes. The volume of water flowing into the reservoir was assessed, and SWAT Calibration and Uncertainty Procedures (SWAT-CUP) were used to analyze the sensitivity of the variables that influenced the volume of water flowing into the reservoir (Zhang *et al.*, 2021), which was represented in the Global Sensitivity Analysis. Adjusted coefficients were used as the criteria for model selection.

$$R^2=\left[\frac{\sum_{i=1}^{n}(O_i-\bar{O})(P_i-\bar{P})}{\sqrt{\sum_{i}^{n}(O_i-\bar{O})}\sqrt{\sum_{i=1}^{n}(P_i-\bar{P})^2}}\right] \qquad \text{Eq. 3}$$

$$\mathrm{NSE}=1-\frac{\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}(O_i-\bar{O})^2} \qquad \text{Eq. 4}$$

$$\mathrm{PBIAS}=\sum_{i=1}^{n}\frac{(O_i-P_i)}{\sum_{i=1}^{n}(O_i)}\mathrm{x}100 \qquad \text{Eq. 5}$$

in which n = number of samples used in the simulation model

O_i = values obtained from real measurements

P_i =estimated values from the SWAT model

$\bar{P}$ = mean of data from the model

$\bar{O}$ = mean of the total data from the measurement

RESULTS AND DISCUSSION

Effects of land-use change

To determine the effects of land-use change on the volume of water flowing into the Mun Bon reservoir, the Markov's change technique was applied between A. D. 2019 and A.D. 2029 to predict each type of land-use change that occurs each year and indicate whether the change will affect the volume of water flowing into the Mun Bon reservoir in the Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, as demonstrated in Table 1. The SWAT model was applied to determine the relationship between the rainfall amount, flow, and topography of the area and the effects of long-term land use on the volume of water flowing into the Mun Bon reservoir (Elsadele *et al*., 2019; Chotchaiwong and Wijithosum, 2019; Wijikosum and Sriburi, 2008; Gyawali *et al.,* 2013). Fig. 3 shows land use in the study area in the Mun River basin (Juan *et al.,* 2013; Kim and Choi, 2020), Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province. In A.D. 2019, most of the areas were forest areas, represented by a vast green segment in the study area, followed by cassava cultivations areas, as represented by the red segment scattered across the study area, with concentration around the water sources in the upper part of the Mun River in Moo 9, Bann Taling Chan, and possible expansion into the green segment of Tublan National Park in the east. Some cassava cultivation areas were scattered across Lum Huai Hin Tom and Lum Huai Nok Ko Ro in the northeast and other water sources in the southwest in Moo5 and Klong Saphan Hin. Sugarcane areas were located in Moo5, Moo10, and Moo11. Other areas were used for other activities.

Fig. 4 shows the pattern of land use in the study area in Mun River basin, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in A.D. 2029. Based on this figure, land use would change from that in A.D. 2019 due to the expansion of cassava cultivation areas (red areas) into forest areas (green areas) along the Mun River including the Mun River itself, Huai Hin Tom, Huai Nok Ko Ro. In Moo 9, the forest areas would be converted into areas for other purposes. Notably, more than half of the forest areas were converted into cassava and sugarcane cultivation areas, with slightly increasing and decreasing changes.

Based on the prediction of land use in the study area in the Mun River basin and its branches in Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, among the 16 types of land use from A.D. 2019 to A.D. 2029 depicted in Table 1, Fig. 3, and Fig. 4, cassava cultivation areas had the highest increase of 11.23 km^2. Sugarcane cultivation areas had the second highest increase of 1.49 km^2 and abundant forest areas had the least increase of 0.003 km^2. Besides, in the study area, forest area was the type of land use with the greatest decrease (i.e., 13.50 km^2). The paddy areas had the second highest decrease of 0.38 km^2. Mixed fruit areas had the least decrease of only 0.0001 km^2. LUC change is one of the main contributing factors affecting discharge and water quality in watersheds due

Table 1. Land-use change for the study areas in the Mun watershed area in Chorakae Hin Sub-district from 2019 to 2029.

								Land Use 2019-2029									
LU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1	419.77	-60.32	-325.85	15,924.93	4,116.91	121.33	77.94	-320.07	-331.15	-323.78	-332.81	-34.78	-298.87	15,924.11	-231.42	-251.94	34,074.02
2	241.07	-239.02	-504.55	15,746.23	3,938.20	-57.38	-100.77	-498.77	-509.86	-502.48	-511.51	-213.48	-477.57	15,745.40	-410.12	-430.64	31,214.73
3	750.50	270.42	4.884	16,255.66	4,447.64	452.058	408.67	10.66	-0.42	6.96	-2.07	295.96	31.87	16,254.84	99.31	78.80	39,365.73
4	-8,481.26	-8,961.34	-9,226.88	7,023.91	-4,784.12	-8,779.70	-8,823.09	-9,221.10	-9,232.18	-9,224.80	-9,233.83	-8,935.80	-9,199.89	7,023.08	-9,132.45	-9,152.96	-108,342.41
5	-2,763.05	-3,243.14	-3508.668	12,742.11	934.09	-3061.494	-3,104.88	-3,502.89	-3,513.97	-3,506.60	-3,515.63	-3,217.60	-3,481.69	12,741.29	-3,414.24	-3,434.76	-16,851.10
6	558.89	78.80	-186.728	16,064.05	4,256.03	260.446	217.06	-180.95	-192.03	-184.66	-193.69	104.34	-159.75	16,063.23	-92.30	-112.82	36,299.94
7	379.42	-100.67	-366.198	15,884.58	4,076.56	80.976	37.59	-360.42	-371.50	-364.12	-373.16	-75.13	-339.21	15,883.76	-271.77	-292.28	33,428.42
8	758.18	278.09	12.56	16,263.34	4,455.31	459.73	416.34	18.34	7.25	14.63	5.60	303.63	39.54	16,262.51	106.99	86.47	39,488.49
9	750.85	270.76	5.232	16,256.01	4,447.99	452.406	409.02	11.01	-0.07	7.31	-1.73	296.30	32.22	16,255.19	99.66	79.14	39,371.30
10	754.68	274.59	9.058	16,259.84	4,451.81	456.232	412.84	14.84	3.75	11.13	2.10	300.13	36.04	16,259.01	103.49	82.97	39,432.52
11	752.26	272.17	6.64	16,257.42	4,449.40	453.82	410.43	12.42	1.34	8.72	-0.32	297.71	33.63	16,256.60	101.07	80.55	39,393.86
12	452.25	-27.84	-293.37	15,957.41	4,149.39	153.81	110.42	-287.59	-298.67	-291.30	-300.33	-2.30	-266.39	15,956.59	-198.94	-219.46	34,593.70
13	721.01	240.92	-24.609	16,226.17	4,418.14	422.565	379.18	-18.83	-29.91	-22.54	-31.57	266.46	2.37	16,225.35	69.82	49.30	38,893.85
14	-23,943.38	-24,423.47	-24688.999	-8,438.22	-20,246.24	-24241.825	-24,285.21	-24,683.22	-24,694.30	-24,686.93	-24,695.96	-24,397.93	-24,662.02	-8,439.04	-24,594.57	-24,615.09	-355,736.39
15	611.17	131.08	-134.452	16,116.33	4,308.30	312.722	269.33	-128.67	-139.76	-132.38	-141.41	156.62	-107.47	16,115.50	-40.02	-60.54	37,136.36
16	679.96	199.87	-65.663	16,185.12	4,377.09	381.511	338.12	-59.88	-70.97	-63.59	-72.62	225.41	-38.68	16,184.29	28.77	8.25	38,236.98
Total	-27,357.67	-35,039.09	-39,287.59	220,724.91	31,796.47	-32,132.81	-32,827.00	-39,195.13	-39,372.47	-39,254.42	-39,398.92	-34,630.44	-38,855.86	220,711.71	-37,776.71	-38,104.98	0.00

LU: land use, 1: corn, 2: paddy field, 3: abandoned field, 4: cassava, 5: sugarcane, 6: rubber, 7: eucalyptus, 8: abandoned farm, 9: mixed fruit trees, 10: commercially grown bamboo, 11: government offices and institutions, 12: community, 13: completely planted forest, 14: forest, 15: alternating shrub/grove meadow, 16: water source.

to anthropogenic activities, such as increasing population and urbanization, encroachment of forests by agriculture and urban areas, and the degradation of forest resources (Konkul *et al.,* 2014; Waiyasusri *et al.,* 2016). Such changes can result in a decrease in infiltration and, in turn, an increase in the rate and volume of surface runoff (Chotpantarat and Chanyotha, 2003; Fitzpatrick, 2005; Klongvessa *et al.,* 2017), and have a negative impact on water quality, which is a major concern in terms of drinking water supplies (Buda and DeWalle, 2009; Oeurng *et al.,* 2010).

Volume of water flowing into the Mun Bon reservoir

The volume of water flowing into the Mun Bon Reservoir with respect to the results of land use in the study area in Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in A.D. 2019 and A.D. 2029 is outlined in Table 2.

Table 2 presents the prediction results for the volume of water flowing into the Mun Bon reservoir based on the land use in the upper Mun River, which served as the base area for predicting the types of land use affecting the volume of water flowing into the Mun Bon reservoir. In A.D. 2019, or the starting year, the average volume of water flowing into the reservoir per year was equivalent to 96 million cubic meter. The cumulative volume from January to December 2019 was 85.76 million cubic meters or 83.34% relative to the average. In the subsequent 10 years (A.D. 2029) with the usual patterns of land use in the upper Mun River and its branches, the average volume of water flowing into the Mun Bon reservoir would be equivalent to 100 million cubic meter. The volume of water flowing into the reservoir from January 1 to December 31, A.D. 2029 would be 43.76 million cubic meter or 43.76% of the average. The flow into the reservoir was lower than that in A.D. 2019. Such a finding might be due to the reduction in forest areas, which function as natural reservoirs, delaying the flow of natural water. Accordingly, water absorption in the soil decreases.

The land use/cover in a river basin dynamically changes with the evolution of the regional population, climate change, and local policies. Further, the changes in land use serve as a contributing factor in regional or global environmental changes. Therefore, runoff responses to land-use change the regional water flow conditions and available water resources. Many studies have reported that land use plays an important role in streamflow variation (Han, 2018). If the soil infiltration characteristics do not change when the vegetation cover decreases, the base flow increases (Bruijnzeel, 2004). However, this situation is not favorable for regional sustainability development as the soil texture will be compacted. Bonell *et al.* (2010) revealed that The reduction of land

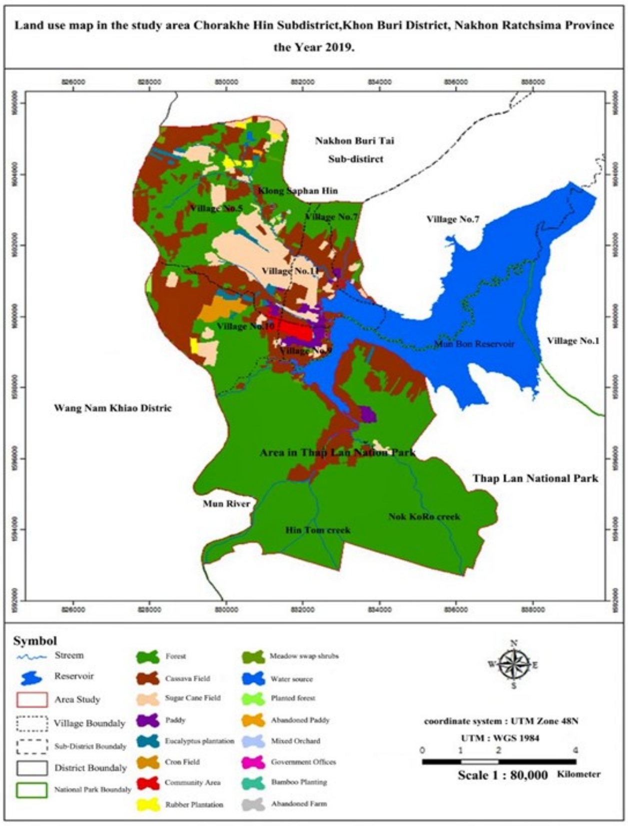

Fig 3. *Land-use map for the study areas, Chorakhe Hin Sub-District, Khon Buri District, Nakhon Ratchasima Province in 2019.*

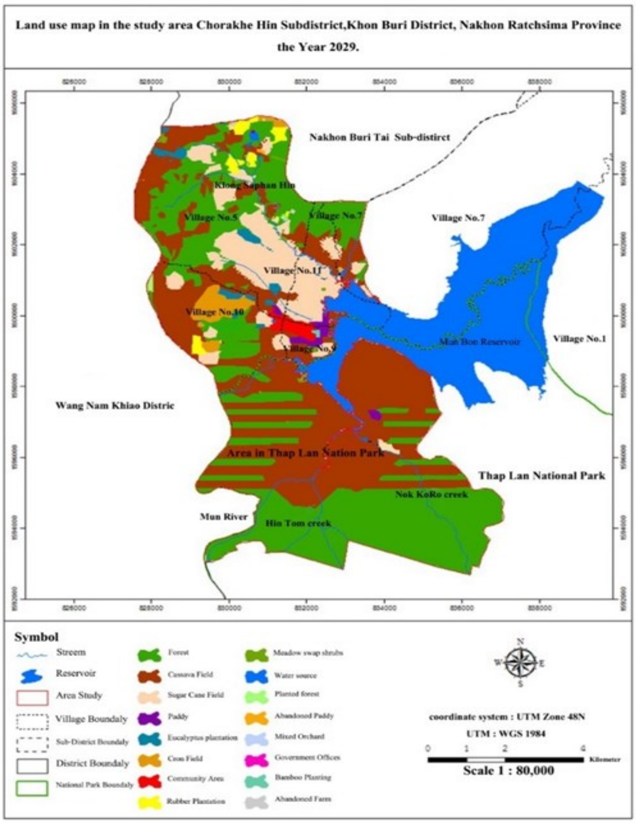

Fig. 4. *Land-use map for the study areas, Chorakhe Hin Sub-District, Khon Buri District, Nakhon Ratchasima Province in 2029.*

Table 2. Volume of water flowing into the Mun Bon Dam Reservoir from the land utilization results of the study area at Mun Upstream Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, 2019 and 2029.

Land use	**Average total year (million cubic meters)**	**Accumulated from 1 Jan. – 31 Dec. of each year**	
		Volume of water (million cubic meters)	**% compared to the annual average**
Year 2019	96	85.76	89.34
Year 2029	100	43.76	43.76

cover when changing the original land-use. It' induces a decrease in infiltrated water and affects groundwater recharge. Bradshaw *et al.* (2007) assessed the relationship between floods and forest area changes, and found that afforestation is helpful in the reduction of the frequency and severity of floods. Guo *et al.* (2008) examined the deforestation of natural forests over Poyang Lake in the Yangtze River basin and observed an increase in monthly and seasonal streamflow during the flooding season, and a decrease in these values during the dry season. According to Li *et al.* (2007), the conversion of farmland to forest and grassland caused the Daqing River to exhibit a decreasing trend in streamflow.

Volume of water in branch canals in each period

Fig. 5 represents the prediction of the average volume of water flowing into the Mun Bon reservoir over 12 months (A.D. 2019) based on land use in the areas of the upper Mun River and its branches. In January-early May 2019, the water volume was less than 0.5 million cubic meters. This is the least amount of water flows into the dung reservoir of the year. In mid-May, the volume of water flowing into the Mun Bon reservoir increased by 1 million cubic meter, decreased from June to mid-July, and then increased from late July to mid-October, with more than 2 million cubic meter of water flowing into the Mun Bon reservoir. The volume of water flowing into the reservoir began to decrease in mid-October and continued to decrease until the end of the year.

Fig. 5 depicts the volume of water flowing into the Mun Bon reservoir based on the usual patterns of land use in A.D. 2029. According to the prediction of the model, the volume of water from the upstream and branches flowing into the Mun Bon reservoir from January to the end of September, A.D. 2029 would be less than 1 million cubic meters nearly every month. In fact, the volume of water will markedly increase to 3.5 million cubic meters from late September to the end of October and sharply decrease from November to December 2029. Remarkable water flow into the reservoir from late September to late October might occur due to water flowing from the upstream forest directly to the reservoir without resting in the upstream area owing to the conversion of the area into agricultural areas for crops, such as cassava, sugarcane, and corn.

A previous study (Niu and Sivakumar, 2014) revealed that possible land-use changes may have more evident impacts on low flow; therefore, understanding the streamflow responses (especially the extreme flow) to land-use changes is necessary for the region. Further, assessing the streamflow responses to land-use changes is an important step for forecasting reservoir

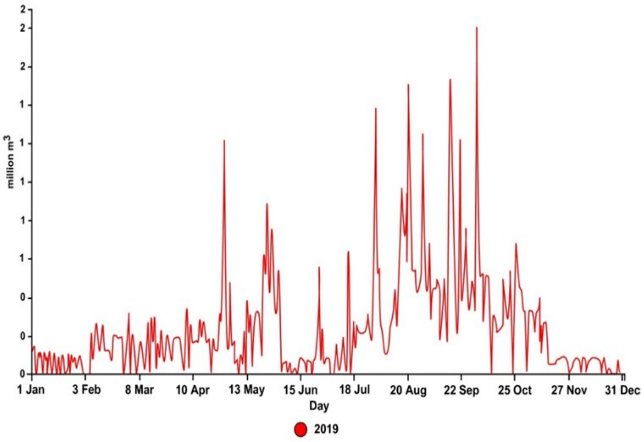

Fig. 5. *Volume of water flowing into the Upper Mun Reservoir based on the results of land use for the Mun Mun watershed area, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in 2019.*

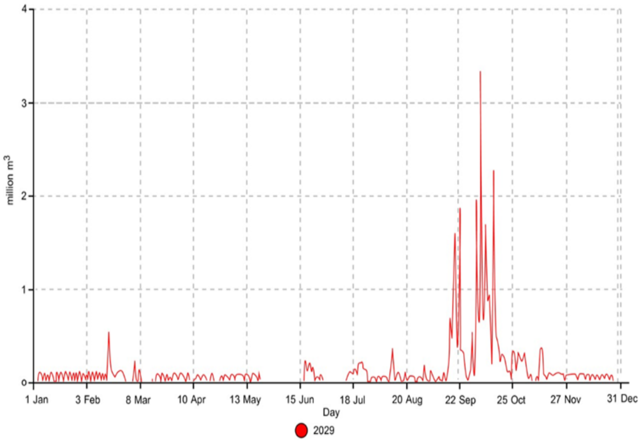

Fig. 6. *Volume of water flowing into the Upper Mun Reservoir based on the results of land use for the Mun Mun watershed area, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in 2029.*

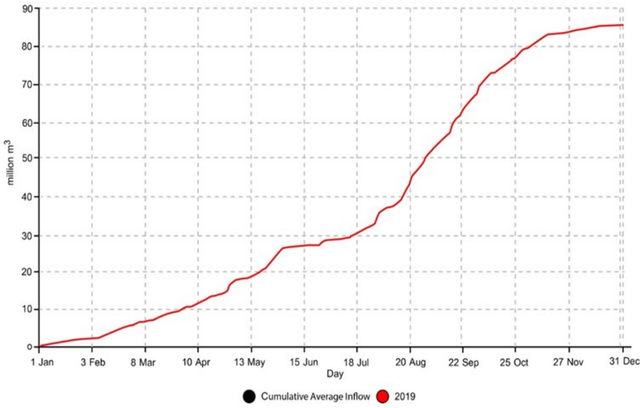

Fig. 7. *Volume of water flowing into the Mun Bon Reservoir that accumulates owing to land use in the Mun Upstream area, Chorakae Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, the year 2019.*

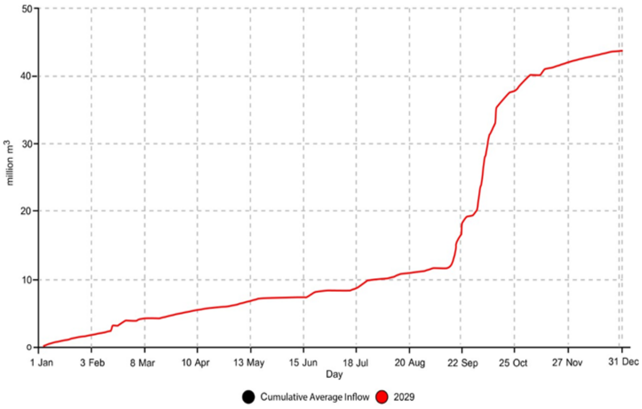

Fig. 8. *Volume of Water Flowing into the Mun Bon Reservoir that accumulates owing to land use in the Mun Upstream area, Chorakae Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, the year 2029*

inflow, and will be useful for promoting sustainable socio-economic development of the Zhanghe agricultural irrigation district.

The average annual surface runoff will affect Evapotranspiration (ET). Surface runoff and impacts on water yield (WY) were identified to decrease over an 18-year period. In contrast, ET and the base current increased. This increase was partly due to an increase in forest and water resources. An increase in forest cover increases the rates of infiltration and transpiration, resulting in increased basal and ET flows. In addition, the decrease of forest areas resulted in an increase in ET and a reduction in WY the stream fell (Bi *et al.*, 2009).

Volume accumulation of water flowing into the Mun Bon reservoir

The volume of water flowing into the Mun Bon reservoir accumulated based on the land use of the study area in the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in A.D. 2019 and A.D. 2029 is depicted in Fig. 7.

The volume of water flowing into the Mun Bon reservoir that accumulated from land use in the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, and Nakhon Ratchasima Province in A.D. 2019 is shown in Fig. 7. Water flowed into the Mun Bon reservoir on January 1, 2019. The line representing the water that accumulated in the reservoir remained straight with similar slopes, indicating that the flow of water into the reservoir remained consistent, except from late September to late October, when the slope increased as the volume of water increased during the monsoon. Subsequently, the slope declined in November and remained unchanged until December. The Soil Water Assessment Tool (SWAT), a physically based, continuous time model, which is computationally efficient, uses readily available inputs and enables long-term impacts. SWAT has been successfully utilized by many researchers (Neitsch *et al.,* 2011).

The volume of water flowing into the Mun Bon reservoir that accumulated from land use in the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, and Nakhon Ratchasima Province in A.D. 2029 is shown in Fig. 8. Water flowed into the reservoir from January 1, A.D. 2029. The line representing the water that accumulated in the reservoir remained straight with similar slopes, indicating that water flow into the reservoir remained consistent. After late September, the slope sharply decreased until late October as the volume of water flowing into the reservoir markedly increased during the monsoon. This result differs from that of A.D. 2019, in which the slope gradually increased. The difference might be attributed to a reduction in areas that

Table 3. Volume of water in Mun Bon Reservoir based on land-use patterns in the Mun watershed area in Chorakae Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province, 2019 and 2029

Land use	**Volume of water in the reservoir**		**Volume of water in the reservoir that is practical**	
	Volume of water (million m^3)	**% compared to the water level**	**Volume of water (million m^3)**	**% When compared to the water level**
Year 2019	70	50	62.95	45
Year 2029	49	35	42.00	30

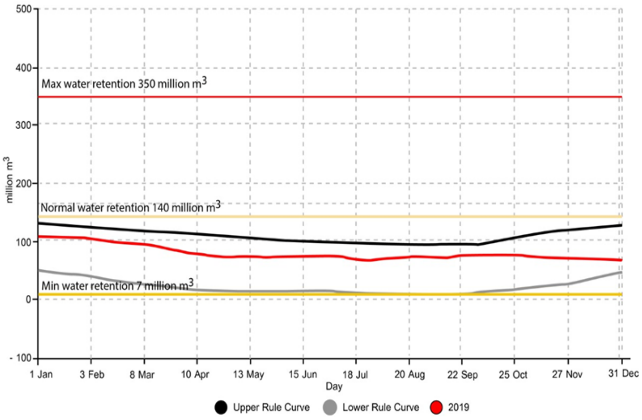

Fig. 9. *Volume of the Mun Bon reservoir based on types of land use at the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in A.D. 2019*

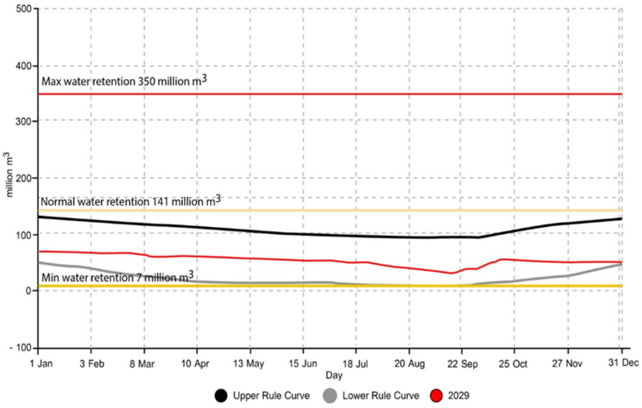

Fig. 10. *Volume of the Mun Bon reservoir based on types of land use at the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in A.D. 2029*

delay and absorb water flow, causing the water to flow abruptly into the reservoir. In late October, the slope markedly decreased and remained unchanged until December.

Volume of water storage in Mun Bon

Construction of the Mun Bon reservoir began in 1980 and was completed in 1997. The Mun Bon reservoir can store 350 million cubic meter of water. Under typical conditions, the reservoir stores 141 million cubic meter. The lowest amount of water stored by the reservoir was 7 million cubic meter. The soil reservoir is 32.7 meters high; the reservoir crest level was +230.70 meters; the reservoir crest height was 880 m; the reservoir crest width was 8.00 meters; the total area of the project 77.28 square kilometers; and the irrigation area was 72.21 square kilometers. The Mun Bon dam reservoir has an ungated service spillway, 10 m wide × 10 m long, with two slots and a +221 m spillway crest (compared with the level of stored water). The highest rate of water discharge was 960 million cubic meters per second. The river outlet had two gate panels; its diameter is 2.45 x 2.45 meters. The reinforced concrete square pipe was 1.50 meters in length. The left was a reinforced concrete square pipe for the canal outlet, with a diameter of 2.45 x 2.85 meters and the highest rate of water discharge of 11.2 million cubic meters per second and + 204.5 meter invert elevation (compared with the level of stored water). In contrast, the right is a reinforced concrete square pipe, with a diameter of 1.15 x 1.15 meters and the highest water discharge of 1.37 million cubic meters per second.

The water storage results based on land use in the study area at the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in A.D. 2019 and A.D. 2029 are outlined in Table 3.

Table 3 presents the volume of water at the Mun Bon reservoir based on the types of land use in the study area at the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, and Nakhon Ratchasima Province. In A.D. 2019, the volume of water was equivalent to 70 million cubic meter, which accounted for only 50% of the stored water. The actual volume of water use was 62.95 million cubic meter, which was lower than the usual water volume and accounted for 45% of the volume of water in the Mun Bon reservoir based on the land-use model for the study area at the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in A.D. 2019.

LUC is a major factor that alters flow regimes. Many studies have evaluated the impact of LUC on the flow regime (Kashaigili, 2008; Kashaigili and Majaliwa,2013; Khoi and Suetsugi, 2014). Understanding the influence of LUC on river flow regimes is important for sustainable catchment management. LUC can change flood frequency, flood severity, base flow, and annual mean discharge (Liu *et al*., 2003). Deforestation and conversion to arable land or grassland are usually accompanied by an increase in surface runoff or total discharge (Chang, J.H., 1993; Lal, R., 1993).

Fig. 9. presents the volume of the Mun Bon dam reservoir based on the types of land use in the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, and Nakhon Ratchasima Province in A.D. 2019. The average volume of water flowing into the Mun Bon dam reservoir was less than 100 million cubic meter, which is 45% lower than the usual storage of 141 million cubic meter. Forest areas have been transformed into agricultural areas. Consequently, water seepage through the soil surface and water retention in the soil were reduced. As a result, most of the rainfall to become runoff flowing into the river, resulting in an increase in annual runoff volume, consistent with the findings of Tangtham and Yuwananont, who studied the impact of land use change and runoff characteristics in the water-

shed This resulted in an increase in water flow and intensified causing flooding problems in the area near the Mun Bon reservoir (Tangtham and Yuwananont, 1996). By decreasing forest area, the amount of runoff increased. Baiku used models to study the relationship and describe the change trend in land use from forests to agricultural areas, community areas, and natural environments. As a result, hydrological processes in the watershed were found to be changed. The rainfall was found to lead to less seepage in to the soil. Accordingly, surface runoff increases, leading to a higher amount of runoff at the end of the rainy season (Baiku *et al*., 2021) .

Fig. 10 shows the volume of the Mun Bon reservoir based on the types of land use in the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, and Nakhon Ratchasima Province in A.D. 2029. The average volume of water flowing into the Mun Bon reservoir was 30 million cubic meter, a value lower than that in A.D. 2019.

The volume of water in the Mun Bon reservoir based on the types of land use in the upper Mun River, Chorakhe Hin Sub-district, Khon Buri District, and Nakhon Ratchasima Province would be lower in A.D. 2029 relative to A.D. 2019. Fig. 9 shows the volume of water in the Mun Bon reservoir based on the types of sustainable land use in the Chorakhe Hin Sub-district, Khon Buri District, Nakhon Ratchasima Province in A.D. 2029. The average volume of water in the dam reservoir based on usual land use in the upper Moon River study area would be as high as 102.16 million cubic meters or 72%, leading to a higher storage level in A.D. 2029.

Conclusion

The model predicting the volume of water flowing into the Mun Bon reservoir from the Mun River and branches revealed 16 types of land use: 1) corn, 2) paddy field, 3) abandoned paddy field, 4) cassava, 5) sugarcane, 6) rubber, 7) eucalyptus, 8) abandoned field, 9) mixed fruit, 10) bamboo for commercial purposes, 11) government offices and institutes, 12) community, 13) planted forest, 14) natural forest, 15) grassland land alternated with shrub/grove, and 16) river source. The Markov chain technique was used to determine the rate of change for each type of land use from A.D. 2019 to A.D. 2029 to predict land use results. Many factors have been found to induce remarkable changes in the last ten years. Compared with other purposes of land use, the highest conversion of land would occur to expand cassava cultivation areas, with 11.23 square kilometers. The second highest land conversion would occur to expand sugarcane cultivation areas, with 1.49 square kilometers. Notably, the forest areas and paddy fields decreased by 13.50 square kilometers and 0.38 square kilometers, respectively. As the simulation of the volume of water flowing into the Mun Bon reservoir based on CLUES and SWAT models was considered, the patterns of land use had an average of 96 million cubic meter per year and the actual water volume in the reservoir was 42 million cubic meter.

ACKNOWLEDGEMENTS

The authors acknowledge the funding support from the Agricultural Research Development Agency (Public Organization), Thailand (ARDA). We appreciate Nakhon Ratchasima Provincial Irrigation Office, Regional Irrigation Office 8 for permission to explore research areas and we appreciate the helping to collect the data.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Baiku, P., Tongdeenok, P. & Kaewjampa N. (2021). Application of SWAT and CLUE-S models in streamflow and land use prediction in the upper Khwae-Noi subwatershed, Nakhonthai district, Phitsanulok province. *Thai Journal of Forestry*, 40(2), 39-55.
2. Bi, H., Liu, B., Wu,S., Yun, L., Chen, Z. & Cui, Z. (2009). Effects of precipitation and land use on runoff during the past 50 years in typical water shed in loess plateau. *China Int J Sediment Res*, 24, 352-364. https://doi.org/10.1016/s1001-6279(10)60009-1.
3. Bonell, M., Purandara, B. K., Venkatesh, B., Krishnaswamy, J., Acharya, H.A.K., Singh, U.V., Jayakumar, R., & Chappell, N. (2010). The impact of forest use and reforestation on soil hydraulic conductivity in the Western Ghats of India: implications for surface and sub-surface hydrology. *J Hydrol*, 391, 47–62. https://doi.org/10.1016/j.jhydrol. 2010.07.004.
4. Boonrawd, S., Anusontpornperm, S., Thanachit, S., Kheoruenromne, I. & Janjirawuttikul, N. (2021). Characteristics and fertility capability of cassava growing soils under different annual rainfall conditions in Northeast Thailand. *Khon Kaen Agriculture Journal*, 49, 1034-1046. https://doi:10.14456/kaj.2021.92 .
5. Bradshaw, C.J.A., Sodhi, N.S., Peh, K.S.H. & Brook, B.W. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. *Global Chang Biol*, 13, 2379–2395. https://doi.org/10.1111/j.1365-2486.2007.01446.x.
6. Bruijnzeel, L.A. (2004). Hydrological functions of tropical forests: not seeing the soil for the trees. *Agr Ecosyst Environ*, 104,185–228. https://doi.org/10.1016/j.agee.01.015.
7. Buda, A.R.&DeWalle, D.(2009). Dynamics of stream nitrqate sources and flow pathways during stormflows on urban, forest and agricultural watersheds in central Pennsylvania, USA. *Hydrological Processes*, 23, 3292-3305.https://doi:org/10.1002/hyp.7423.

8. Chang, J.H.(1993). Hydrology in humid tropical Asia. Hydrology and Water Management in the Humid Tropics, Cambridge University Press: Cambridge, UK, pp. 55–66.
9. Chotchaiwong, P. & Wijitkosum, S. (2019). Predicting urban expansion and urban land use changes in Nakhon Ratchasima city using a CA-Markov model under two difference scanario. *Land*, 8, 1-16. https:// doi:10.3390/land8090140.
10. Chotpantarat, S. & Boonkaewan, S. (2018). Impacts of land – use changes on watershed discharge and water quality in a large intensive agricultural area in Thailand. *Hydrogical Sciences Journal*, 63, 1386-1407. https://doi.org/10.1080/ 02626667.2018.1506128.
11. Dessu, S. B. & Melesse, A. M. (2012). Modelling the rainfall–runoff process of the Mara River basin using the Soil and Water Assessment Tool. *Hydrological Process*, 26, 4038-4049. https://doi.org/10.1002/hyp.9205.
12. Elsadele, W. M., Ibrahim, M.G. & Mahmod, W. E. (2019). Runoff hazard analysis of wadi Qena watershed, Egypt based on GIS and remote sensing approach. *Alex. Eng. J*, 58, 377-385. https://doi.org/10.35762/AER.20 18.4 0.1.4.
13. FitzPatrick, E.A. (2005). Soil microscopy and micromorphology. Interactive soil science, Abadeen. School of Biological Science, University of Aberdeen, St. Machar Drive, Aberdeen, Scotland, UK.pp. 1-8.
14. Gassman, P. W., Reyes, M. R., Green, C. H. & Arnold, J. G. (2007). The soil and water assessment tool: Historical Development, applications, and future research directions. *American Society of Agricultural and Biological Engineers*, 50, 1211-1250. https://doi:10.13031/ 2013.23637.
15. Guo, H., Hu, Q. & Jiang, T. (2008). Annual and seasonal streamflow responses to cli-mate and land-cover changes in the Poyang Lake basin. China. *J Hydrol*, 355, 106–122. https://doi.org/10.1016/j.jhydrol.2008.03.020.
16. Gyawali, S., Techato, K., Monprapussorn, S. & Yuangyai, C. (2013). Integating land use planting for U-tapao river basin, Thailand. *Procedia-Social and Behavioral Sciences*, 91, 556-563.https:// doi:10.1016/j.sbspro.2013.08.454.
17. Han, D.D. (2018). Runoff simulation of Xilin River driven by multi-source data and impact of land cover change on runoff. Inner Mongolia Agricultural University, Inner Mongolia.
18. Harylenko, S. B., Bodoque, J. M., Srinivasan, R., Zucarelli, G.V. & Mercuri, P. (2016). Assessment of the soil water content in the pampas region using SWAT. *Catena*, 137, 298-309. https://doi.org/10.1016/j.catena.2015.10.001.
19. Hua, W., Chun, H., Sun, S. & Zhou, L. (2015). Assessment Climatic impacts of future land use and land cover change projected with the CanESM2 model. *International Journal of Climatology*, 35, 3661-3675. https://doi:10.1002/joc.4240.
20. Jamshidi, M. & Tajrishy, M. (2010). Modelling of point and non-point source pollution of Nitrate with SWAT in the Jairod river watershed Iran. *International Agricultural Engineering Journal, 19, 23-31*. [Google Scholar].
21. Juan, H., Jinyan, Z., Yan, H., Wu, F. & Deng, X. (2013). Evalution of the Impacts of land use on water quality: A case study in the cholu lake basin. *The Scientific World Journal*, 1, 1-7. https:// doi:10.1155/2013/329187.
22. Kashaigili, J.J. (2008). Impacts of land-use and land-cover changes on flow regimes of the Usangu wetland and the Great Ruaha River, Tanzania. Phys. *Chem. Earth*, 33, 640–647. https://doi.org/10.1016/j.pce.2008.06.014.
23. Kashaigili, J.J. & Majaliwa, A.M. (2013). Implications of land use and land cover changes on hydrological regimes of the Malagarasi river, Tanzania. *J. Agric. Sci. Appl*, 2, 45–50. https://doi:10.14511/JASA.2013.020107.
24. Khoi, D.N. & Suetsugi, T. (2014). Impact of climate and land-use changes on hydrological processes and sediment yield—A case study of the Be River catchment. Vietnam. *Hydrol. Sci. J*, 59, 1095–1108. https://doi.org/10.1080/02626667.2013.819433.
25. Kim, T.G. & Choi, K.S. (2020). A study on water quality change by land use change using HSPF. *Environment Engineering Research*, 25, 123-128. https://doi.org/10.4491/eer.2019.105.
26. Klongvessa, P., Lu, M., Chotpantarat, S. (2017). Response of the flood peak to the spatial distribution of rainfall in the Yo, river basin, Thailand. *Stochastic Environmental Research and Risk Assessment*, 32, 2871-2887. https://doi.org/s00477-018-1603-4.
27. Konkul, J., Rojborwornwittaya, W.& Chotpantarat, S. (2014). Hydrogeologic characteristics and groundwater pontentiality mappaing using potential surface analysis in the Huay Sai area, Phetchaburi province, Thailand. *Geosciences Journal*, 18, 89-103. https://doi:10.1007/s12303-013-0047-6.
28. Lal, R. (1993). Challenges in agriculture and forest hydrology in the humid tropics. Hydrology and Water Management in the Humid Tropics. Cambridge University Press: Cambridge, UK; pp. 395–404.
29. Li, C. & Fang, H. (2021). Assessment of climate change impacts on the streamflow for the Mun River in the Mekong Basin, Southeast Asia: Using SWAT model. *Catena*, 201, 1-13. https://doi.org/10.1016/j.catena.2021.105199.
30. Li, H.Z. (2007). Research on the influence of land use/ cover change on hydrological factors based on SWAT model. Hebei Normal University, Hebei
31. Liu, J., Liu, M., Zhuang, D. & Zhang, Z. (2003). Study on spatial pattern of land-use change in China during 1995-2000. *Science in China series D Earth Sciences*, 46 (4):373-384. https://10.1360/03yd9033.
32. Meyer, N., Berger, J., Constantin, E. J. & Justes, E. (2019). Cover crops reduce water drainage in temperature Climates: A meta-analysis. *Agron.Sustain.Dev*, 39, 1-11. https://doi.org/10.1007/s13593-018-0546-y.
33. Neitsch, S.L., Arnold, J.G., Kiniry, J.R.& Williams, J.R. (2011). Soil and water assessment tool theoretical documentation version 2011. Taxas water resources institute technical report No.406. Taxas A&M university system, College station, Texas, USA, pp. 1-14.
34. Niu, J. & Sivakumar, B. (2014). Study of runoff response to land use change in the East River basin in South China. *Stoch Env Res Risk A*, 28, 857–865. https:// doi:10.1007/s00477- 13-0690-5.
35. Phangam, T., Noinmsai, N. & Konggrit, N. (2020). Spatial potential analysis for sustainable water resource management lower Lam Cheang Krai basin with Geographic information system. *Acadermic journal*, 4, 71-81.
36. Phanurak, W. & Suwanwaree, P. (2013). Land use change in Thaplan nation park, the part of Dong Phra

Yayen-Khao Yai forest complex world Heritage, *Thailand. Naresuan University Journal*, 21, 39-48.

37. Praweenwongwuthi, S., KaewmuangmoonSukanlaya, T., Sukanlaya, C., Choenkwan, A. & Rambo, T. (2017). Recent changes in agricultural land use in the riverine area of Nakhon Phanom Province, Northeast Thailand. *Southeast Asian Studies*, 6(2), 211-246. https://doi: 10.20495/seas.6.2_207.
38. Oeurng, C., Sauvage, S., sanchez-erez, J.Asessment of hydrology sediment and particulate organic carbon yyield in a large agricultural catchment using the SWAT model. J. Hydrol, 40, 145-153. https://doi.org/10.1016/j. hydrol.2011.02.017.
39. Rode, M., Thiel, E., Franko, U., Wenk, G. & Hasser, F. (2009). Impact of selected agricultural management options on the reduction of nitrogen loads in three representative meso scale catchments in central Germany. *Science of the Total Enviroment*, 407, 3459-3472. https://doi: 10.1016/j.scitotenv.2009.01.053.
40. Sang, L., Zhang, C., Yang, J., Zho, D. & Yun, W. (2011). Simulation of land use spatial pattern of towns and villages based on CA-makov model. *Mathematical and Computer Modelling*, 54, 938-943. https://doi.org/10.1016/j.mcm.2010.11.019.
41. Tangtham, N. &Yuwananont, S. (1996). Impact of land use changes on streamflow and flow characteristics of Pasak basin. *Thai Journal of Forestry*, 15, 98-110.
42. Verburg, P. H., Soepboer, W., Veldkamp, A. &. Espaldon, M. V. O. (2002). Modelling the spatial dynamics of regional land use: *The Clues-S model. Environment Management*, 30(3), 391-405. https:// doi: 10.1007/s00267-002-2630-x.
43. Wijikosum, S. & Sriburi, T. (2008). Impact of urban expansion on water demand: the case study of Nakhonrachasima city, Lan Ta Kong watershed. *Nakhara J. Environ. Des.Plan*, 4, 69-F88.
44. Waiyasusri, K., Yumuang, S. & Chotpantarat, S. (2016). Mornitoring and predicting land use chages in the Huai Thap salao watershed area, Utthaithani Province, Thailand, using the CLUE-s model. Environmental Earth Sciences, 76, 1-16. https://doi: 10.1007/s12665-016- 5322-1.
45. Wang, C., Boithias, L.,Ning, Z., Han, Y., Sauvage, S., erez, JMS., Kuramochi, K.& Hatano, R. (2016). Comparison of Langmuir and Freundlich adsorption equations within the SWAT-K model for assessing potassium environmental losses at basin scale. *Agricultural Water Management,* 108, 205-211. https://doi.org/10.1016/j.agwat.2016.08.001.
46. Yagoub, M. M. & Bizreh, A. A. (2014). Predition of land cover change using Markov and cellular automata models case of Al-Ain, UAE, 1992-2030. *J Indian Soc Remote Sens*, 42, 665-671. http:// doi 10.1007/s12524-013-0353-5
47. Zhang, Y., Qiao, L., Chen, C., Tian, L. & Zheng, X. (2021). Effects of organic ground covers on soil moisture content of urban green spaces in semi-humid areas of China. *Alex. Eng. J*, 60, 251-259. https://doi.org/10.1016/j.aej.2020.08.001.