



Assessing the change of water quality and quantity in the upper basin of Thac Ba reservoir under the impacts of future land-use scenarios

Ngoc-Tue Nguyen¹ · Duc-Trung Nguyen¹ · Thuong-Quang Tran¹ · Xuan-Truong Nguyen¹ · Van-Tien Pham¹

Received: 17 October 2022 / Accepted: 7 February 2023 / Published online: 4 March 2023
© The Author(s), under exclusive licence to Springer Nature Switzerland AG 2023

Abstract

Variability in land use is anticipated to affect regional hydrologic conditions and have a wide range of implications on water resources and human health across the world, particularly in developing countries like Vietnam. Land-use/land-cover change has been a significant difficulty for the social–economic development of upland areas in northern Vietnam in recent years, owing to its relationship with downstream environmental concerns such as water quantity and quality. The Geographical Information System (GIS) and SWAT model (Soil and Water Assessment Tools) were used in this study to assess the impacts of land-use change on streamflow and sediment runoff under various future development scenarios based on economic circumstances. The Thac Ba reservoir watershed was chosen for examination because it is vital for agriculture, hydropower generation, and household water supply to communities living in the watershed's proximity and downstream. It is estimated that 75–85% of the total yearly rainfall falls between May and October. When it comes to sediment runoff in the Thac Ba watershed, increasing monthly flow discharge increases mean monthly sediment runoff during the rainy season in all situations, but decreasing monthly flow discharge decreases mean monthly sediment runoff during the dry season in all scenarios. The findings demonstrated that the seasonal streamflow had been affected in a more sophisticated manner than had been observed in earlier forest conversion scenarios. Both the rainy and dry seasons saw an increase in average streamflow, which is a beneficial thing in terms of streamflow. When compared to the baseline scenario, average values in the rainy season climb by 4.72 and 8.04 percent, respectively, in scenarios 2.3 and 2.4 (extreme situations) (1.9 percent in extreme scenario). An in-depth investigation indicates that the average flow rises throughout the year, but continues to fall in November, December, and January. According to the scenarios, the most significant changes are shown in May (ranging from 2.77 percent to 15 percent) and June (ranging from 2.11 percent to 14.7 percent). Furthermore, in scenario 2.4, during dry months, the average maximum streamflow is reduced by approximately 3.5 percent in November and December, but increases in March and April.

Keywords Thac Ba reservoir · Watershed management · Surface water hydrology · Simulation Land use/land cover change · Soil and water assessment tool (SWAT) · Geographic information system (GIS)

Introduction

Vietnam, a developing country in Southeast Asian, has strong ties in the fields of Agriculture and Water (Adamson PT et al. 2009; Viet H et al. 2019). It covers the total area of about 331,212 km² of which the agricultural area makes up 39.25% of Vietnam's total land area. The agriculture sectors accounts for 10,000 km², of which 70% of the

area is cultivated by rice and 30% of the area is cultivated with other foods such as corn, potatoes, cassava, vegetables, fruits. Meanwhile, the progress of key projects in agricultural processing should be accelerated in alignment with promoting the productivity of current processing plants to serve demand for domestic consumption and export. Additionally, Vietnam's tropical region is very prone to soil erosion and surface runoff. Approximately 40% of natural areas are at risk of erosion (Nguyen 2010). In recent years, most of the forested areas, particularly in Central Vietnam, were

✉ Ngoc-Tue Nguyen
tue.nguyenngoc@hust.edu.vn

¹ Hanoi University of Science and Technology, Hanoi, Vietnam

converted into agricultural lands, which resulted in surface runoff and soil erosion (Phuong and Chuong 2013). The Aluoi district in Central Vietnam is under high socio-economic pressure, which resulted in various natural hazards such as flooding and soil erosion. Lack of data is one of the main obstacles for policymakers in this area.

Several studies on simulating hydrological processes have revealed significant regional water resource vulnerabilities to changes in both temperature and precipitation patterns over the last several decades. Policy and technical measures could be taken primarily at the local and regional levels to avoid or reduce the negative effects of land-use and climate change on water resources, particularly agriculture, where water availability, water demand, and water quality issues are regarded as primary concerns in Vietnam. Regarding the land-use changes, potential impacts may include changes in hydrological processes which would cause impacts in the supply of domestic, agricultural water, flash flood, and water quality. However, most studies do not quantify contributions of change for individual land-use and climatic variability to different hydrological responses. Therefore, distinguishing effects of individual land-use changes from concurrent climate variability poses a particular challenge (Pan et al. 2021; Lioubimtseva et al. 2005; Tollan 2002). With the development of information technology, quantitative estimations of the hydrological components under individual land-use change and climate variation are significant issue for understanding potential water resources problems and will be helpful in making better planning decisions. With the purpose of analyzing the impact of different land-use/land-cover activities in the upstream of the watershed, which are increasing in the area due to the high population growth rate, and deforestation as well as urbanization, the water quantity and quality are affected by the land-use changes and management practices (Son et al. 2022) (Fig. 1).

As a result, deforestation and urbanization not only raise the risk of floods during the wet season and of water scarcity during the dry season, but they also encourage soil erosion. As a result, the creation of scenarios is an absolute requirement. For the purpose of facilitating enhanced evaluation and decision making, a scenario-based analysis is developed. In the process of developing and assessing the effects of environmental change on water resources and the management of water quality, it is common practice to first conduct an analysis of a number of potential future scenarios. The scenarios are built based on the potential actions that may occur in the future. Therefore, in order to apply the SWAT model as a tool for determining the impacts of various land-use changes on streamflow and sediment in the Thac Ba watershed, the several scenarios were created and analyzed. Some studies were done to determine the impacts of different land-use changes on streamflow and sediment. (Dao N Khoi et al. 2021, Khoi, Dao N et al. 2022).

Method

Model calibration and validation

Streamflow calibration and validation

Initial run and sensitivity analysis

A preliminary, uncalibrated model run predicted a lower average streamflow than recorded (Tue Ngoc Nguyen et al 2021). One possibility is that rainfall levels observed at three distinct gauges were underestimated. In light of these findings, total rainfall amounts in this study were increased by 9.1% using the WorldClim dataset's spatially comparable values of three rainfall gauges (Hijmans et al. 2005). This improved the model's simulated average streamflow to 126.7 (m³/s), but required extra calibration of the other parameters listed below. This was done using SWAT to see which parameters have the biggest impact on streamflow. the groundwater delay time (GW DELAY), the baseflow alpha factor (Alpha Bf), recharge to the deep aquifer (RCHRG DP), and slope length factor (SLF) (SLSUBBSN).

Calibration and validation

With these five parameters (CN2, GW DELAY, Alpha Bf, RCHRG DP, and SLSUBBSN), the streamflow may be precisely calibrated (Neitsch et al., (2011) Soil and Water Assessment Tool: Theoretical Documentation 2009). This was done between January 1, 1992 and December 31, 1997, then between January 1, 1998 and December 31, 2003, as described in the SWAT theoretical documentation and user manual (Neitschet et al. 2009). The period from January 1st to December 31st, 1991 was used as a warm-up period to help initialize the model before the calibration period. The CN2 affects how precipitation is divided between surface runoff and infiltration. Currently, there are no regional databases tying CN to local land use and soil types for the Thac Ba watershed. The Thac Ba watershed is in areas with small, shallow, and local groundwater resources, according to the WHYMAP Groundwater Resources Map of the World (2012). Because the baseflow was overestimated when comparing observed and modeled hydrographs, the GW DELAY parameter was increased from 31 to 40 days to spread out the groundwater contribution to baseflow (GW DELAY = 40 days). The baseflow recession constant (Alpha

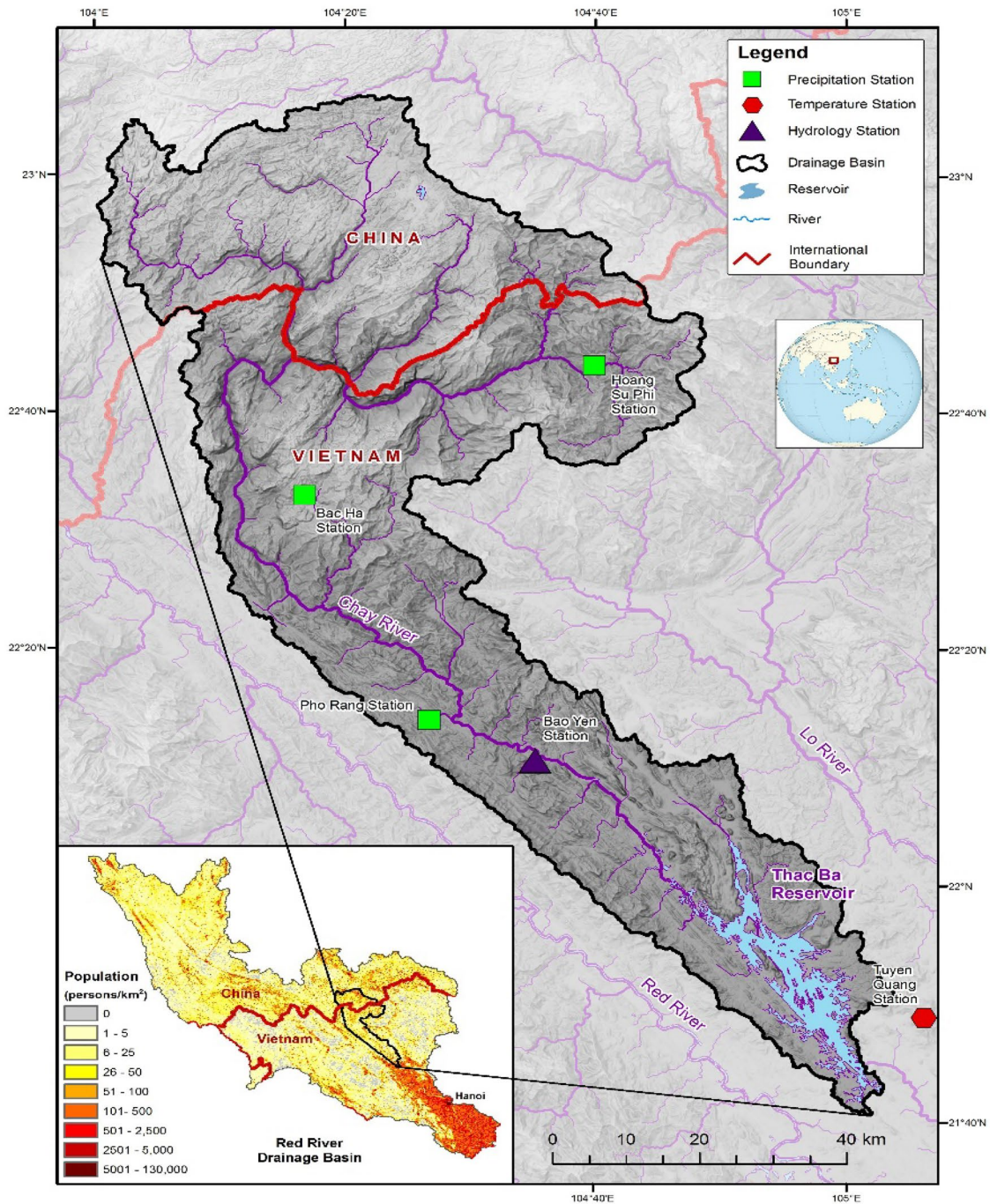


Fig. 1 The Thac Ba watershed: Topography, Surface Water and Monitoring Stations [ref]

Bf) was also increased from 0.048 to 0.9, improving the sensitivity of groundwater flow to changes in groundwater recharge. Van Griensven et al. (2005) found Alpha Bf to be marginally significant in streamflow sensitivity. Alpha Bf can range from 0 to 1, with 1 being the strongest potential groundwater flow response. Percolation losses to deep aquifers were set to zero, meaning that no infiltrating water is

lost to deep aquifers. The decrease in RCHRG DP increased overall flow by 3.48 percent. Due to the complicated topography in the watershed, most agriculture and plantation was done on terraces. The slope length (SLSUBBSN) of each plot in agricultural fields with slopes more than 7% was reduced by 20% to account for the slope break created by the field's supply of terraces.

Sediment calibration and validation

Through parameter calibration overestimated dry and rainy season sediment runoff. Highland farms are prone to erosion due to steep slopes, significant rainfall (80% during the rainy season), and erodible soil. For example, agricultural operations and plants on sloping terrain may result in less sediment runoff than predicted by the original SWAT parameters established for different situations. SWAT performed a sensitivity analysis to discover which factors affect sediment runoff the most. They were USLE support practice factor (USLE P), USLE cover or management factor (USLE C), USLE soil erodibility (USLE K1), and Slope length factor (USLE K1) (SLSUBBSN).

Using monthly simulated sediment runoff from Bao Yen station during the period 1992–1997, the four most sensitive sediment runoff parameters (USLE P, USLE C, USLE K1, and SLSUBBSN) were calibrated. Table 2 shows the values fitted for the adjusted parameters. They obtained USLE P (0.1–0.9) and USLE C (0.12–0.55) factor values for paddy rice (2 cycles and 1 cycle), cassava, maize, and soybean in the Lo watershed in Northern Vietnam (2010). Using data from Vezina et al. (2006), an average USLE K factor of 0.022 was assumed (2010). The slope length (SLSUBBSN) of each plot was lowered by 20% in agricultural areas with slopes greater than 7% to accommodate for the supply of terraces. Sediment runoff was verified for the years 1998 to 2003 using parameters altered during calibration.

Building developing scenarios

According to the Decision 116/2006/QĐ-TTg of the Prime Minister of Vietnam for Master plan for socio-economic development of mountainous provinces including Yen Bai, Lao Cai, and Son La in Northern Vietnam in the period of 2006–2020, the industrial development trend than the others (44% in economic structure). The industrial development will lead to the development of infrastructure, roads, urban areas, etc. (<http://www.yenbai.gov.vn/vi/Pages/dinhhuongpattrien.aspx>). Based on this, two scenarios were created and analyzed.

Developing scenario 1

The forest land converted to bare land by agricultural activities during the seeding time and deforestation activities by 15, 25, 37, 50, 75% and extreme conversion by 100%. The current land use is used as baseline scenarios. The replacement is carried out from the upstream to downstream of the research area. The land-use change's description is given in Fig. 2

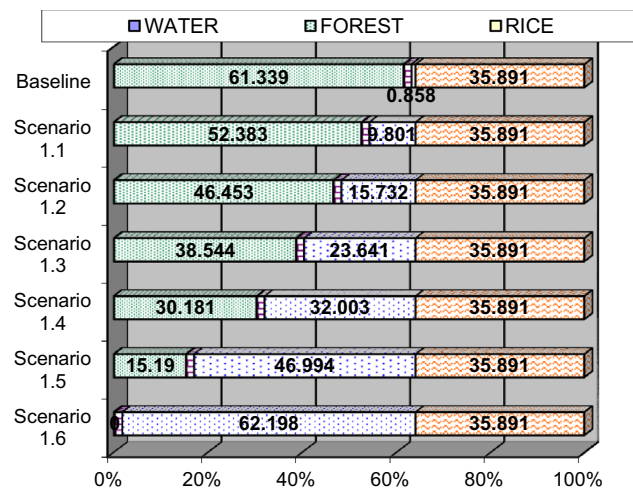


Fig. 2 Conversion of forest to bare land

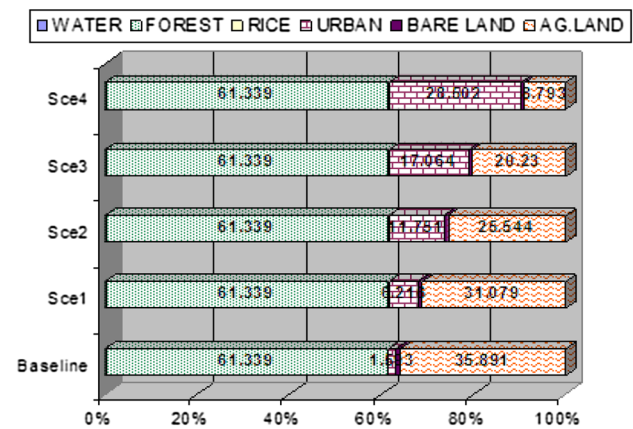


Fig. 3 Conversion of agricultural to urban land

Developing scenario 2

In this scenario, the agricultural land converted to urban land by 13, 29, 44, and 75% and the current land use is also used as baseline scenarios. The replacement is carried out from the upstream to downstream in the research area (Fig. 3).

Results and discussion

Calibration and validation

Impact of land-use changes on flow and sediment discharge under developing scenario 1

The simulations under all land-use change scenarios indicated that the deforestation has significant impact on stream-flow characteristics (Figs. 4, 5, 6, 7, 8, 9, 10, 11). The results shown in Fig. 3 and summarized in Table 1 first indicate

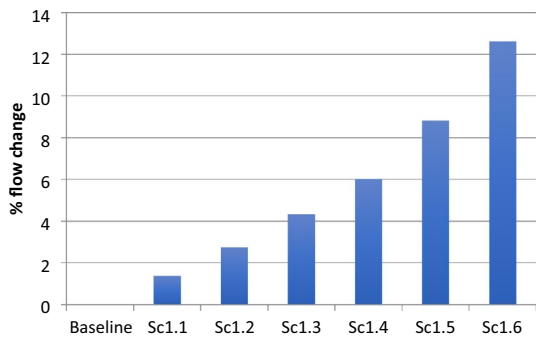


Fig. 4 Percentage of average surface flow change with the different land-use scenarios

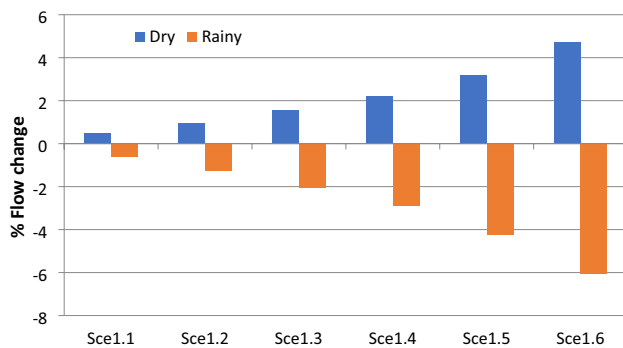


Fig. 5 Percentage stream flow change in dry and rainy season with the different scenarios

Fig. 6 Average monthly flow change with conversion of forest to bare land by 15%

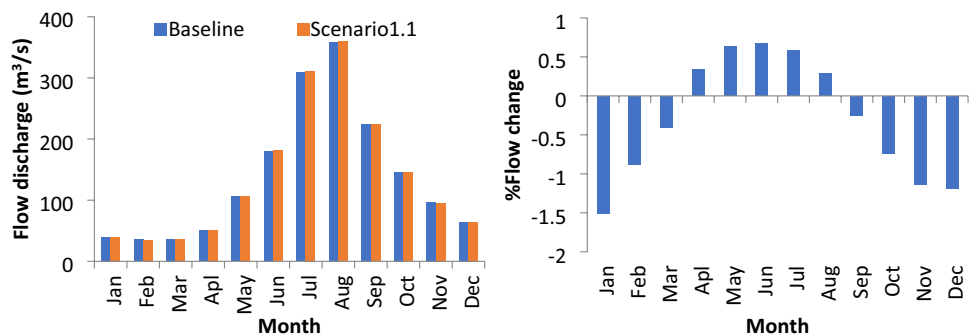
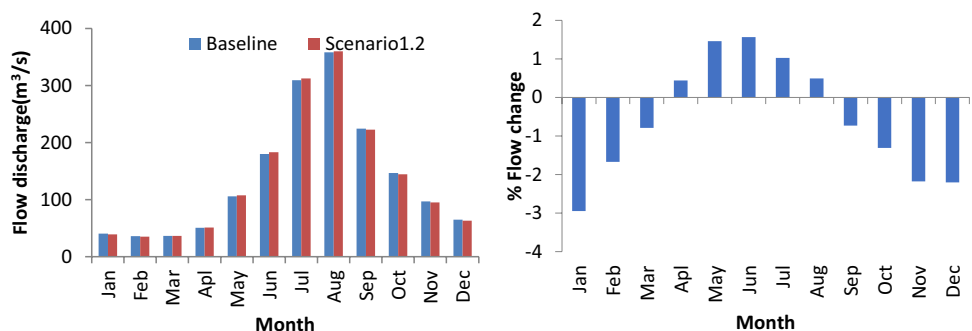


Fig. 7 Average monthly flow change with conversion of forest to bare land by 25%



that the average annual surface runoff significantly increased from Scenario 1.1 to Scenarios 1.6 (ranging from 1.37% to 12.63%) which compared with baseline scenarios. This implies that the conversion of forest to bare land makes increasing flow rate on the surface and also increasing sediment runoff, especially in the high slope watershed.

Furthermore, one of the most serious concerns about the conversion of forests to other land uses is the loss of water storage during the dry season and flooding during the rainy season. Figure 3 depicts the average seasonal stream flow changes caused by various scenarios. The conversion of 15% to 100% forest to bare land increased streamflow in the rainy season by 0.51 percent to 4.51 percent and decreased streamflow in the dry season by 0.62% to 6.05%.

The trend of monthly flow change is more clearly presented in Figs. 6, 7, 8, 9, 10, 11. The highest decreasing streamflow due to land-use change takes place in January November and December which ranged from 1.52 to 15.65% (January); 1.13 to 11.37% (November) and 1.14 to 11.74% (December), respectively. However, the streamflow has a trend of increase in April to August. The maximum change is in May (ranging from 0.64 to 8.50%, respectively) and June (range from 0.67 to 6.39%, respectively), while in the other months it increases slightly (April, July, and August).

In the above analysis, the land-use change not only affected streamflow, but also affected sediment runoff. The results are given in Figs. 12, 13, 14, 15, 16, 17, which

Fig. 8 Average monthly flow change with conversion of forest to bare land by 37%

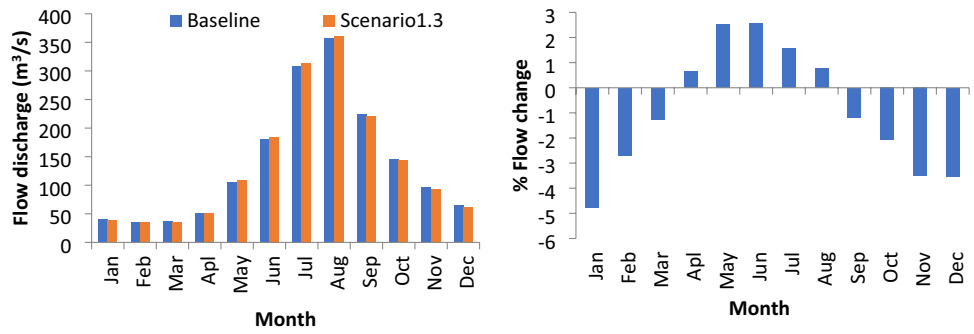


Fig. 9 Average monthly flow change with conversion of forest to bare land by 50%

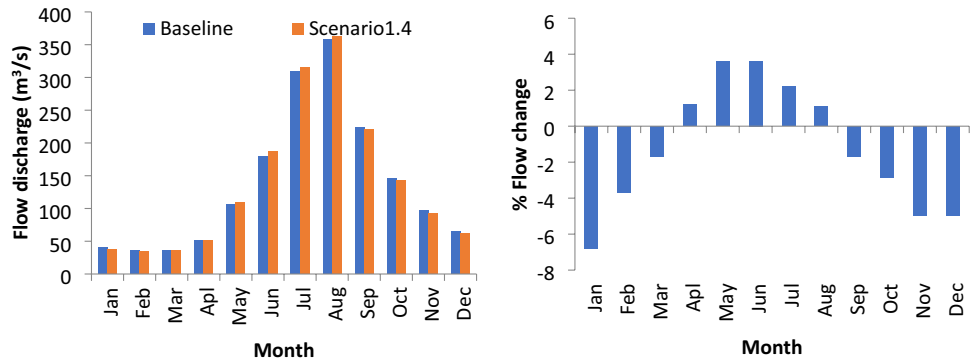


Fig. 10 Average monthly flow change with conversion of forest to bare land by 75%

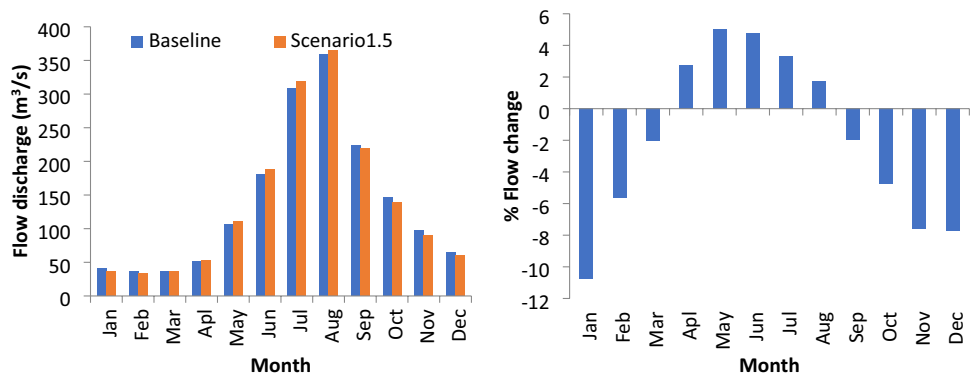


Fig. 11 Average monthly flow change with conversion of forest to bare land by 100%

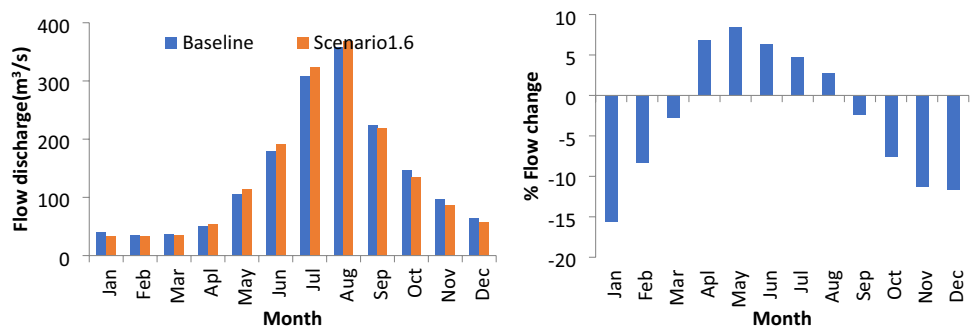


Table 1 Percentage of average surface flow change with the different land-use scenarios

Scenarios	Baseline	Sc1.1	Sc1.2	Sc1.3	Sc1.4	Sc1.5	Sc1.6
%	0	1.37	2.73	4.32	6.02	8.83	12.63

Fig. 12 Average monthly sediment runoff change with conversion of forest to bare land by 15%

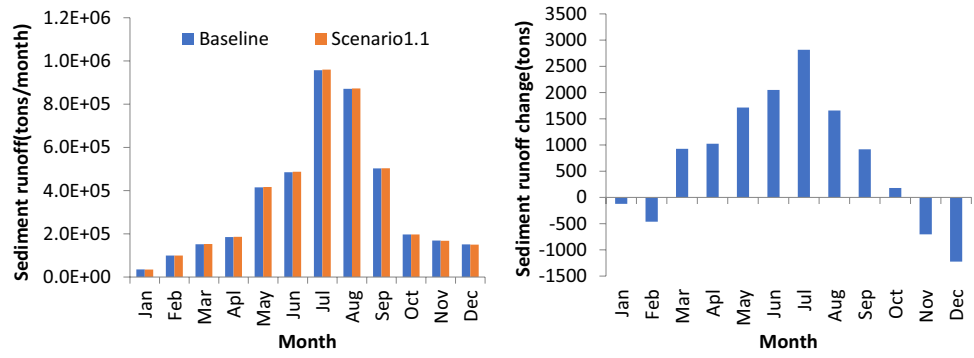


Fig. 13 Average monthly sediment runoff changes in conversion of forest to bare land by 25%

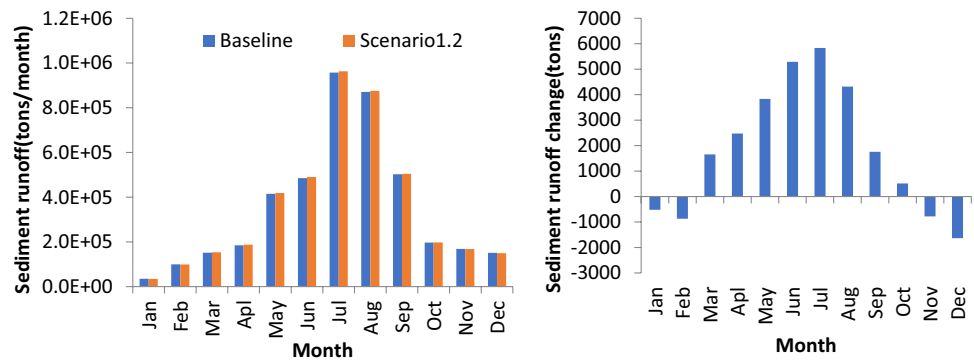


Fig. 14 Average monthly sediment runoff change in conversion of forest to bare land by 37%

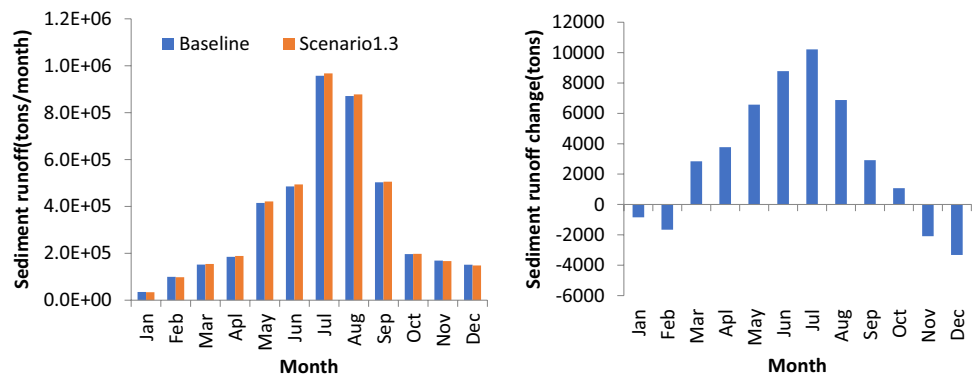


Fig. 15 Average monthly sediment runoff change in conversion of forest to bare land by 50%

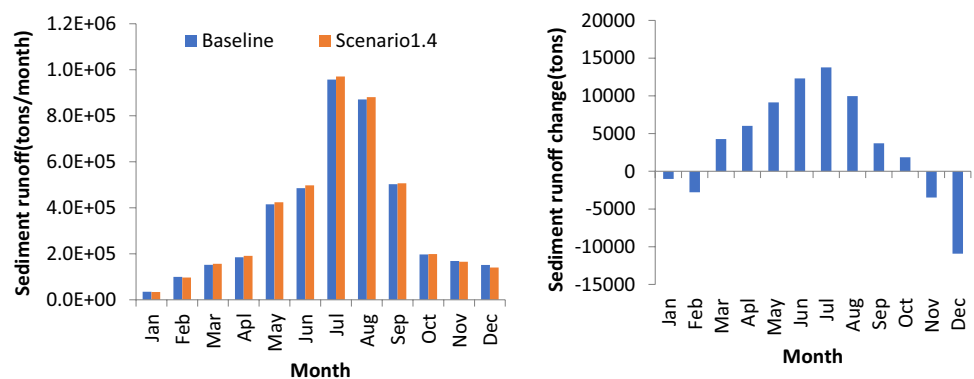


Fig. 16 Average monthly sediment runoff change in conversion of forest to bare land by 75%

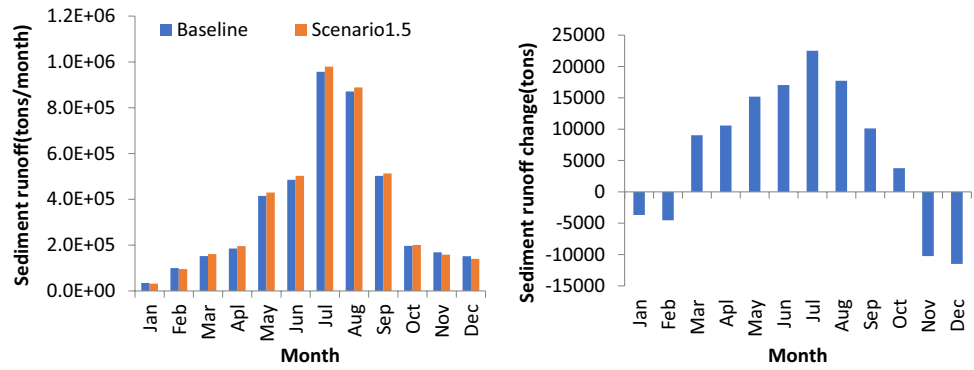


Fig. 17 Average monthly sediment runoff change in conversion of forest to bare land by 100%

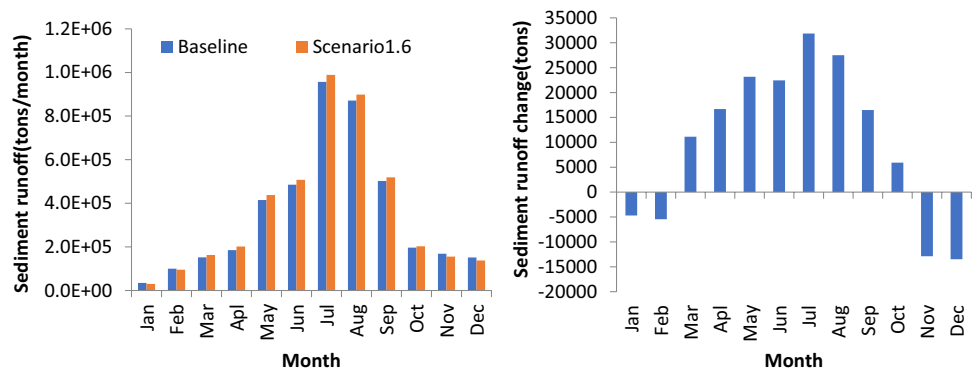


Table 2 The average sediment runoff change with different scenarios (tons/month)

Baseline	Scenario1.1	Scenario1.2	Scenario1.3	Scenario1.4	Scenario1.5	Scenario1.6
3.52×10^5	3.53×10^5	3.54×10^5	3.56×10^5	3.57×10^5	3.62×10^5	3.66×10^5

Table 3 Percentage of average surface flow change under land-use scenarios 2

Scenarios	Baseline	Scenario2.1	Scenario2.2	Scenario2.3	Scenario2.4
%	0	2.48	6.27	9.42	14.72

present the effects of conversion of forest to bare land on sediment runoff in the watershed.

With regard to sediment runoff in the Thac Ba watershed under various scenarios, it can be seen that increasing monthly flow discharge increases mean monthly sediment runoff in the rainy season, while decreasing monthly flow discharge decreases mean monthly sediment runoff in the dry season for all scenarios. Deforestation degrades the protective surface layers of the watershed, indicating that soil erosion rates increase significantly under each scenario. The results are described in Table 2, which indicates that the average sediment runoff varied between 0.3 and 4.1% for Scenarios 1.1–1.6.

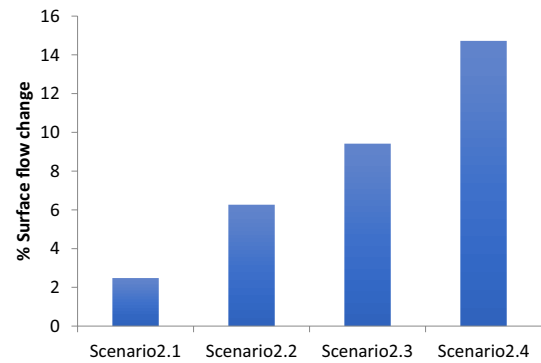


Fig. 18 Percentage of average surface flow change under land-use scenarios 2

Impact of land-use changes on flow and sediment discharge under developing scenario 2

With the conversion of agricultural land to urban land, the surface runoff increases by 2.5 to 14.7% under the scenarios (Scenario 2.1 to Scenario 2.4) compared with the baseline

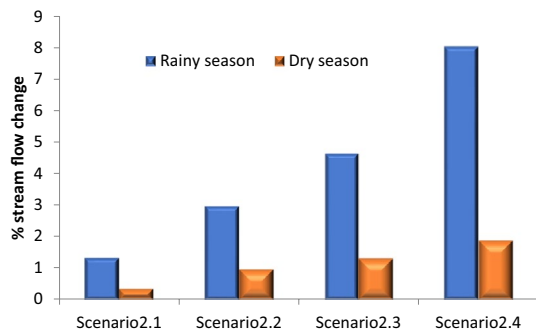


Fig. 19 Percentage stream flow change in dry and rainy season with scenarios 2.1–2.4

scenario (Table 3 and Fig. 18). The expansion of urban areas decreases infiltration (CN2 = 98) and significantly increases surface runoff in the watershed.

Additionally, the results suggested that the seasonal streamflow was altered in a more intricate manner than in past forest conversion scenarios. In terms of seasonal streamflow, both the rainy and dry seasons saw a rise in average flow (Fig. 19). In scenarios 2.3 and 2.4 (extreme scenarios), average values increase by 4.72 percent and

8.04 percent, respectively, in the rainy season, and modestly increase in the dry season, compared to the baseline scenario (1.9 percent in extreme scenario). For a more extensive analysis (see Figures 19, 20, 21, 22, 23), while the average flow increases in all seasons, it continues to decrease in November, December, and January. Through scenarios, the most significant changes occur in May (ranging from 2.77 percent to 15 percent) and June (ranging from 2.11 percent to 14.7 percent). Additionally, during dry months, the average maximum streamflow is reduced by approximately 3.5 percent in November and December, but increases in March and April under scenario 2.4.

The form of changes is similar to the deforestation scenarios but with increasing trend in both rainy and dry seasons. In this case, the sediment runoff in rainy months is significantly increased, reaching a maximum of 17.74% in June with scenario 2.4 as indicated by Figs. 24, 25, 26, 27. The Table 4 shows that the total sediment runoff change under scenarios 2. This result can be mainly attributed to the type of the applied land-use changes between agricultural and urban lands. The surface of urban area has very low infiltration rate, and thus the erosion rate will be significant increased when the surface runoff increases sharply. That is the reason why the average sediment

Fig. 20 Average monthly flow change with conversion of agricultural land to urban land by 13%

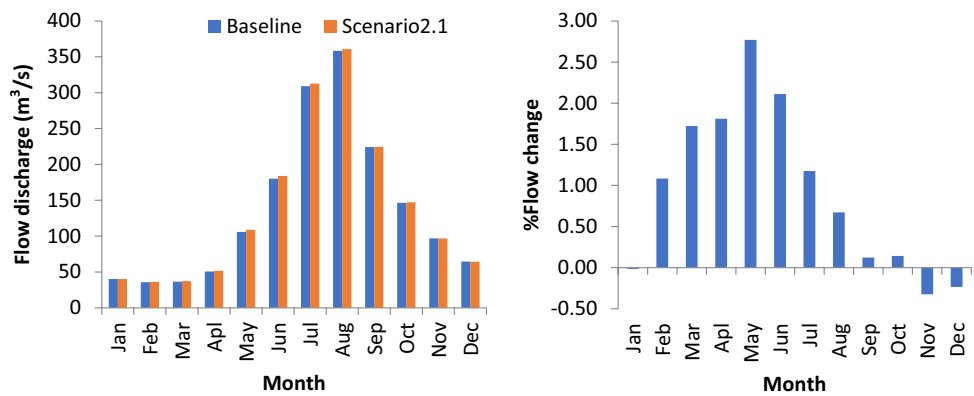


Fig. 21 Average monthly flow change with conversion of agricultural land to urban land by 29%

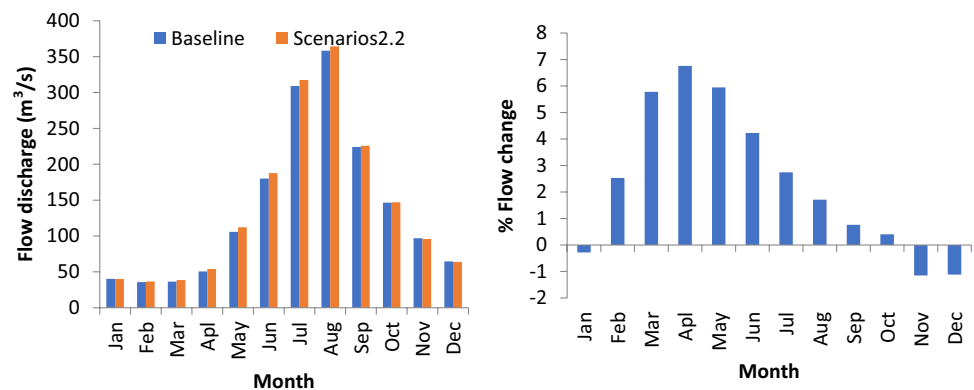


Fig. 22 Average monthly flow change with conversion of agricultural land to urban land by 44%

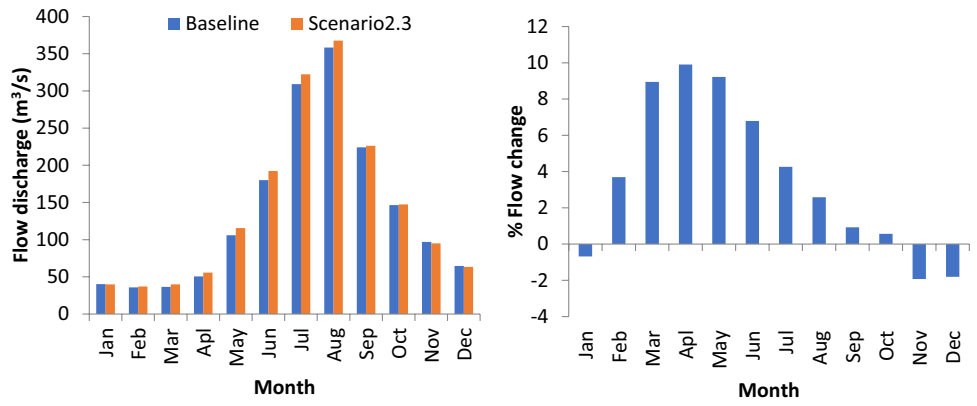


Fig. 23 Average monthly flow change with conversion of agricultural land to urban land by 75%

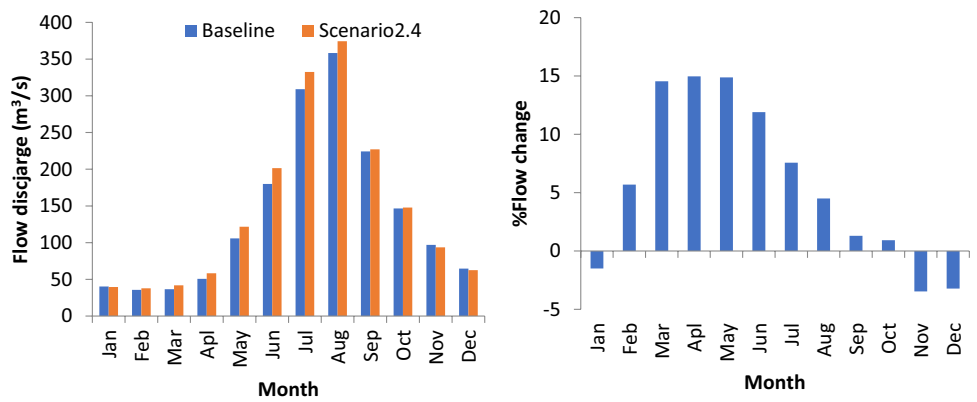


Fig. 24 Average monthly sediment runoff change with conversion of agricultural land to urban land by 13%

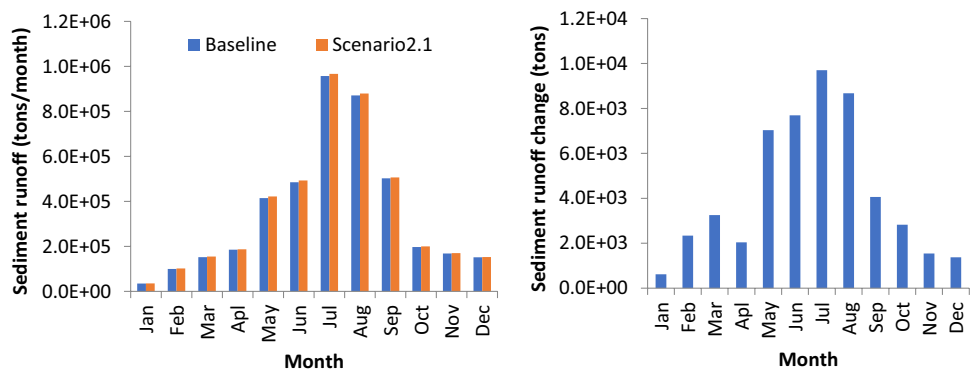


Fig. 25 Average monthly sediment runoff change with conversion of agricultural land to urban land by 29%

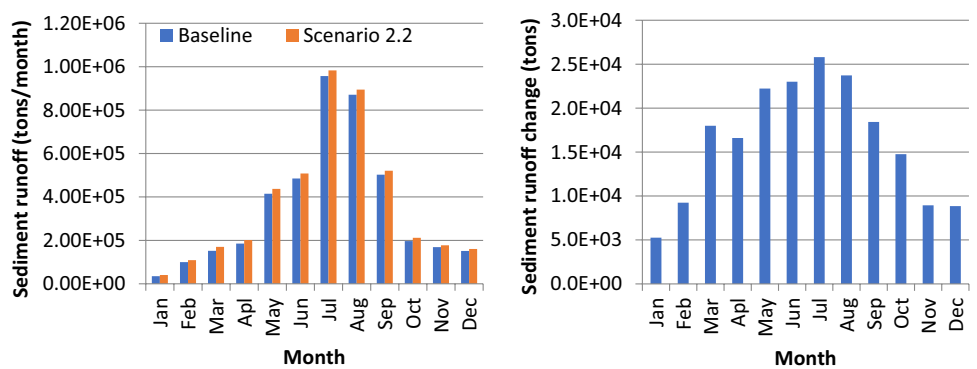


Fig. 26 Average monthly sediment runoff change with conversion of agricultural land to urban land by 44%

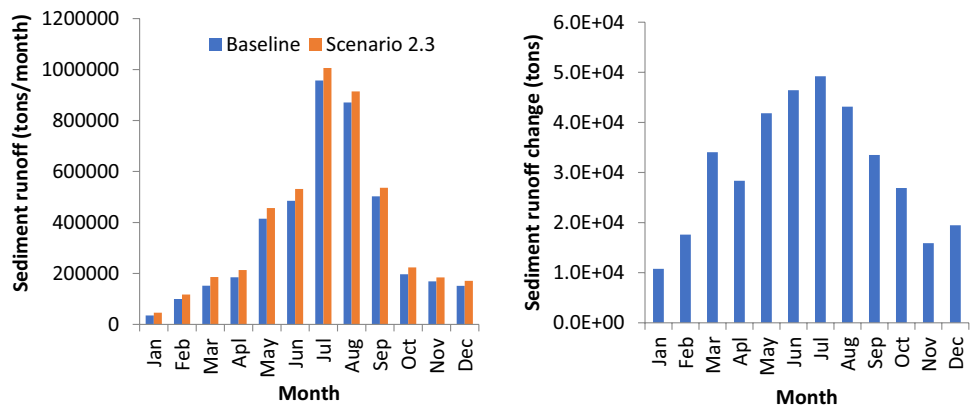


Fig. 27 Average monthly sediment runoff change with conversion of agricultural land to urban land by 75%

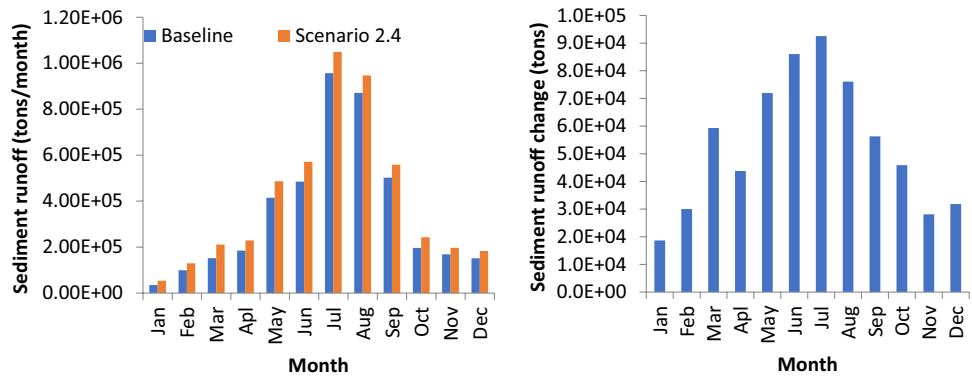


Table 4 The total sediment runoff change under scenarios 2 (tons)

Baseline	Sce2.1	Sce2.2	Sce2.3	Sce2.4
5.06×10^7	5.12×10^7	5.30×10^7	5.50×10^7	5.83×10^7

increased by 12% through the scenarios in a few months (January, November, and December) during dry season despite a decline in streamflow rate. The annual total sediment runoff ranged from 35.9 ton/ha to 43.74 ton/ha.

Conclusion

It is anticipated that changes in land use would bring about regional hydrologic conditions that will bring about a variety of effects on water supply as well as on human health in emerging nations such as Vietnam. In recent years, the transformation of land use and land cover has posed a significant challenge for the social and economic development of upland areas in northern Vietnam. This is because of the connection between land-use and cover change and downstream environmental implications, such as the quantity and quality of water. The results of this research led to the evaluation, with the use of the Geographic Information

System (GIS) and the SWAT model, of the impacts of land-use change on streamflow and sediment runoff (Soil and Water Assessment Tools). The watershed around the Thac Ba reservoir was chosen for exploration because it is used for agriculture, the generation of electricity, and the provision of household water. According to the findings, the seasonal streamflow had been altered in a way that was more complicated than what had been observed in earlier forest conversion scenarios. This was discovered. An increase in the average streamflow was seen throughout both the wet and dry seasons, which is an encouraging development in terms of streamflow. When compared to the baseline scenario, the average values for the rainy season are projected to increase by 4.72 and 8.04 percent, respectively, according to scenarios 2.3 and 2.4, which are considered to be extreme scenarios. On the other hand, the average values for the dry season show only a slight increase (1.9 percent in extreme scenario). Further investigation indicates that the annual average flow rate increases throughout the course of the year, but that it remains on a downward trend throughout the months of November, December, and January. According to the several scenarios, the month of May (with changes ranging from 2.77 percent to 15 percent) and the month of June both see the most significant shifts (ranging from 2.11 percent to 14.7

percent). In addition, the maximum average streamflow during the dry months is predicted to fall by approximately 3.5 percent in November and December under scenario 2.4, but to increase under scenario 2.4 during the months of March and April.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s40808-023-01732-3>.

Author contributions All authors contributed to the study's conception and design including data preparation, data collection, and analysis. The first draft of the manuscript and final version were written by all authors.

Data availability All data generated or analysed during this study are included in this published article (Evaluation of the hydrology and sediment load situations of the upper watershed of Thac Ba reservoir (Vietnam and China) under the impacts of climate changes) (Nguyen and Nguyen 2022).

Declarations

Conflict of interests The authors declare that they have no competing interests.

References

- Adamson PT, Rutherford ID, Peel MC, Conlan IA (2009) The hydrology of the Mekong river. In: Mekong T (ed) Campbell ICBT-TM. Elsevier, San Diego, pp 53–76
- Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. *Intern J Climatol A J Roy Meteorol Soc* 25(15):1965–1978
- Holvoet K, van Griensven A, Seuntjens P, Vanrolleghem PA (2005) Sensitivity analysis for hydrology and pesticide supply towards the river in SWAT. *Phys Chem Earth Parts a/b/c* 30(8–10):518–526
- Khoi DN, Loi PT, Sam TT (2021) Impact of future land-use/cover change on streamflow and sediment load in the be river basin Vietnam. *Water* 13(9):1244. <https://doi.org/10.3390/w13091244>
- Khoi DN, Loi PT, Trang NTT, Vuong ND, Fang S, Nhi PTT (2022) The effects of climate variability and land-use change on streamflow and nutrient loadings in the Sesan, Sekong, and Srepok (3S) River Basin of the Lower Mekong Basin. *Environ Sci Pollut Res* 29(5):7117–7126. <https://doi.org/10.1007/s11356-021-16235-w>
- Lioubimtseva E, Cole R, Adams JM, Kapustin G (2005) Impacts of climate and land-cover changes in arid lands of Central Asia. *J Arid Environ* 62(2):285–308
- Neitsch SL, Arnold JG, Kiniry JR, Williams JR (2011) Soil and water assessment tool: theoretical documentation (2009). Texas Water Resources Institute: College Station, TX, USA, p 618p
- Nguyen NT, Nguyen DT (2022) Evaluation of the hydrology and sediment load situations of the upper watershed of Thac Ba reservoir (Vietnam and China) under the impacts of climate changes. *Model Earth Syst Environ* 8:5595–5610. <https://doi.org/10.1007/s40808-022-01406-6>
- Nguyen TN, Nguyen TX, Van Pham T, Nguyen D-T (2021) Applying the soil and water assessment tool model for integrated lake basin management in northern vietnam: case study of the thac ba reservoir basin. *Environ Eng Sci* 38(11):1027–1035
- Nguyen AH (2010) Comprehensively studying geographical arising and land degradation aiming the purpose of reasonably using land resource and preventing disaster in Binh—Tri—Thien region. Doctor of Philosophy Dissertation. Hanoi.
- Pan T, Zuo L, Zhang Z, Zhao X, Sun F, Zhu Z, Liu Y (2021) Impact of land use change on water conservation: a case study of zhangjiakou in Yongding River. *Sustainability* 13(1):22. <https://doi.org/10.3390/su13010022>
- Phuong TT, Chuong HV (2013) Simulating effects of land use change on soil erosion in Bo River basin in the Central of Vietnam. *Journal of Agriculture and Rural Development*. 2
- Son NT, Le Huong H, Loc ND, Phuong TT (2022) Application of SWAT model to assess land use change and climate variability impacts on hydrology of Nam Rom Catchment in Northwestern Vietnam. *Environ Dev Sustain*. <https://doi.org/10.1007/s10668-021-01295-2>
- Tollan A (2002) Land-use change and floods: what do we need most, research or management? *Water Sci Technol* 45(8):183–190
- Vezina K, Bonn F, Van CP (2006) Agricultural land-use patterns and soil erosion vulnerability of watershed units in Vietnam's northern highlands. *Landscape Ecol* 21(8):1311–1325
- Viet H (2019) The dynamics of agricultural intra-industry trade: a comprehensive case study in vietnam. *Struct Change Econ Dyn*. 49:74–82. <https://doi.org/10.1016/j.strueco.2019.04.004>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.