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Assessment of dam impacts on flow, sediment, and morphology of the Sai Gon-Dong Nai River basin, Vietnam

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Introduction

Sai Gon-Dong Nai (SGDN) River system (Fig. 1) is the backbone for the sustainable development of Ho Chi Minh, Binh Duong, and Dong Nai by supplying essential freshwater sources for approximately 20 million people. It discharges 32.5 billion m^3 of water to the East Vietnam Sea, ranked second to the Mekong River in the South of Vietnam. 36 large dams for irrigation, water supply, and hydropower have been built in the SGDN River basin with a total storage capacity of ~10.6 billion m^3), including several cascade dams, all of which occupy ~32.6% of the total water discharge of the river system. The operations of these dams sometimes do not guarantee flood control for large cities such as Ho Chi Minh and downstream environmental flow (i.e., necessary to control hydrological drought and salinity intrusion). A holistic understanding of the effects of dams on the hydrology and sediment in the SGDN River system is, therefore, of crucial importance for better water resource management and planning. Therefore, this study assesses long-term alterations of discharge and suspended sediment concentration (SSC) in the basin from which the driving factors are then discussed.

Study area

The SGDN River system comprises two main rivers, namely Dong Nai and Sai Gon, in which the Sai Gon River discharges into the Dong Nai River before emptying into the East Vietnam Sea. The SGDN is one of the largest river systems that originates and flows within the territory of Vietnam. Be and La Nga are the two largest tributaries of the SGDN basin, in which Tri An and Dau Tieng are the two greatest hydropower and irrigation dams, respectively. These two dams are important for flood control and environmental flow maintenance downstream.

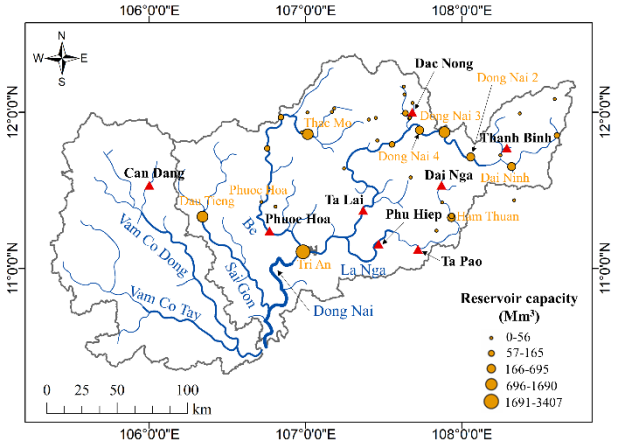

Fig. 1 The location map of the SGDN River Basin.

Materials and methods

Eight hydrological stations are monitoring daily discharge (Fig. 1), four of which are monitoring daily suspended sediment concentration (i.e., Ta Pao, Phu Hiep, Ta Lai, and Phuoc Hoa) in the SGDN basin. The daily discharge data are available from the 1980s to 2021, while the daily SSCs are collected from the 1990s to 2021. The collected data were undergone quality checks before applying statistical analysis.

The cleaned data were analyzed to find the long-term trend by using the Mann-Kendall test. The change year and rate of change (i.e., slope) were found using the Pettitt test and Sens slope method, respectively. Discrepancies between the upstream and downstream stations reveal the effect of climate variability and anthropogenic activities such as river damming and land use land cover changes.

Results and discussions

In the upstream of the Dong Nai River, the discharge at Dac Nong and Thanh Binh (Fig. 1) increased in both flood and dry months from 1981 to 2021 (Fig. 2). The increases in the monthly discharge at these two stations are all statistically significant at 5% significance level, except for June, October, and November at Thanh Binh. For instance, the discharge in February at Dac Nong and Thanh Binh increased by 0.09 $m^3/s/yr$ ($p < 0.001$) and 0.03 $m^3/s/yr$ ($p = 0.01$), respectively. The respective values in September are 0.43 $m^3/s/yr$ ($p < 0.05$) and 0.13 $m^3/s/yr$ ($p = 0.05$). The increases in the discharge at these two stations are driven by natural phenomena, i.e., increases in rainfall.

However, the flood discharge at Ta Lai (downstream station) has decreased, while the dry discharge has increased from 1987 to 2021 (Fig. 2). In September, for instance, the discharge statistically decreased by 8.97 $m^3/s/yr$ ($p < 0.05$). The discrepancy between the upstream and downstream stations shows that the cascade dams in the Dong Nai River (e.g., Dong Nai 2, 3, and 4 dams) have strongly regulated the natural flow in the upper Dong Nai basin.

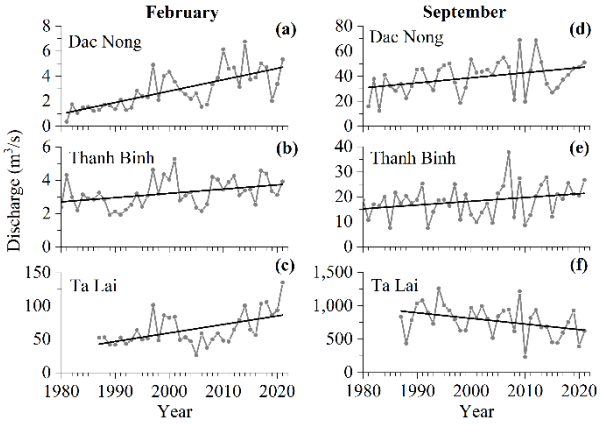

Fig. 2 Long-term trends in the discharge at Dac Nong, Thanh Binh, and Ta Lai in February and September.

The SSC at Ta Lai has increased in all months (some months in both flood and dry seasons are statistically significant) from 1999 to 2021, except for a decreasing trend in July. In February, the SSC at Ta Lai has statistically increased by 1.05 $g/m^3/yr$ ($p < 0.05$) (Fig. 3a). It indicates that the sub-basin between Thanh Binh-Dac Nong and Ta Lai contributes a significant amount of sediment, mainly from deforestation causing more sediment erosion.

At Ta Pao in the La Nga River, the SSC decreased (statistically significant in the flood months) during 1996-2021, which is consistent with the decreasing trend in the long-term (1979-2021) discharge at Dai Nga (Fig. 1). In September, the SSC at Ta Pao decreased by 3.01 $g/m^3/yr$ ($p < 0.05$). Such SSC decrease is mainly because of a reduction in the rainfall in the sub-basin, while the Ham Thuan reservoir (Fig. 1) may contribute partially to the reduction.

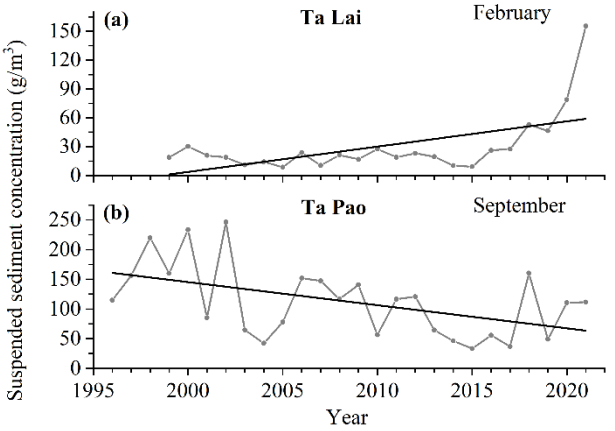

Fig. 3 Long-term trend in the SSC in February at Ta Lai and in September at Ta Pao.

Conclusion

In the upper Dong Nai basin at Dac Nong and Thanh Binh, the flood and dry discharge have increased due to rainfall increase. However, the flood discharges downstream at Ta Lai have decreased caused mainly by cascade dams. In the La Nga sub-basin, the discharge and SSC have decreased by rainfall reduction and dam construction.

Acknowledgment

This work was funded by the project "Assessment of dam impacts on flow, sediment, and morphology of the Sai Gon-Dong Nai River basin" under grant number DTCS2022-002 and by APN "Asia-Pacific Network for Global Change Research" under project reference number CRRP2020-09MYKantoush (Funder ID: https://doi.org/10.13039/100005536).