論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Development of streamflow and sediment load estimation methods and the application to hydro-environmental assessment of the Tonle Sap Lake Basin
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12441号, 授与年月日:2023年3月26日, 学位の種別:課程博士, 審査員:木内 豪,吉村 千洋,中村 恭志,中村 隆志,VARQUEZ ALVIN CHRIST
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12441号, Conferred date:2023/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	Global Engineering for Development, Environment and Society 系コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Engineering)
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

The sparse hydro-meteorological networks hinder hydrological modeling and hydro-environmental impacts assessment in the Tonle Sap Lake (TSL) Basin, which is the largest freshwater body in Southeast Asia and plays a crucial role in sustainable development in Cambodia and the lower Mekong region. Currently, the lake ecosystem is widely under threat from climate change and anthropogenic activities. Although these impacts could be attributed to multiple driving factors including the influence of the Mekong mainstream, information on hydro-environmental impacts from its tributaries is limited. This necessitates a comprehensive hydrological assessment, owing to land use and climate changes, for environmental conservation of the TSL Basin. Therefore, the overall objective of this study is to develop a feasible framework for estimating streamflow and sediment load and application to hydro-environmental impact assessment in data-sparse basins of the TSL.

In the beginning, a comprehensive framework was introduced to assess different gridded precipitation and air temperature products by comparing them with gauge-based datasets and applying the Soil and Water Assessment Tool (SWAT) model for daily streamflow and evapotranspiration (ET) simulations. The precipitation data from Asian Precipitation-Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE), European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis v5 (ERA5), Tropical Rainfall Measuring Mission (TRMM) and Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (GPM) (IMERG) were found to have high correlations with rain-gauged data, and the Southeast Asia-Observation (SA-OBS) and Climate Prediction Center (CPC) were found to match the observed air temperature data. Furthermore, the rainfall from APHRODITE, TRMM and IMERG, combined with SA-OBS-based air temperature data provided improved estimations of daily streamflow. The ET estimated using the TRMM and IMERG datasets showed a better temporal and spatial pattern agreement with ET from Moderate Resolution Imaging Spectroradiometer (MODIS) and Global Land Evaporation Amsterdam Model (GLEAM). This suggests that TRMM and IMERG, in conjunction with SA-OBS air temperature, are reliable for providing streamflow and other water balance components through the SWAT model application. These findings showed that statistical comparisons with gauge data and hydrological evaluation of streamflow are not enough to justify the reliability of the gridded dataset.

Although gridded meteorological data could serve as the hydrological model inputs, model outputs (i.e., sediment load) need to be optimized using ground-based observation. However, model optimization cannot be performed in the ungauged catchment (e.g., the catchment is not monitored in terms of sediment concentration). To solve this problem, a regionalization method, in which model parameters from well-monitored catchments are transferred to ungauged, was used. Therefore, a novel Sediment-Response Similarity (SRS) regionalization method has been proposed, using the SWAT model and Self-Organizing Map to overcome the limitation of the critical attributes of a catchment favoring sediment similarity, which usually exists in the conventional regionalization approaches. It considered the spatiotemporal variations of sediment response and its relationship with rainfall as a catchment attribute and showed the potential to ideally determine hydrological and sediment similarities between gauged and ungauged catchments. The results indicated the comprehensive performance of the SRS method for estimating sediment load in the ungauged catchments by giving an estimation error reduction of up to 7%, compared with the Physical Similarity method. Therefore, the SRS regionalization method proposed in this study is a global alternative method for estimating sediment, as well as other hydrological variables, in ungauged catchments.

Eventually, the above-proposed framework was used to quantify the impacts of climatic variability and land-use change on streamflow and sediment load in the TSL Basin during the last few decades. Climate analysis showed an increasing trend in temperature and a downward trend in rainfall between 2001 and 2020. The land-use change study revealed that there was a substantial decrease in natural forest cover (approximately 45%), with the area decreasing from 37,052 km^2 in 1995 to 20,408 km^2 in 2018. Whereas, the cropland area increased by about 23% from around 30,400 to 37,324 km^2. The hydrological simulation depicts that the early rainy season flows were lower (max. 26% decrease) for 2011-2020 compared to the 2001-2010 time horizons. However, after the wet monsoon season, the streamflow was observed to slightly increase due to the rise in rainfall amount during September and November. A similar change in the seasonal pattern forced by climate variability was found between flow and sediment load. The land-use change enforced streamflow and sediment load to increase by up to 5.83 and 19.57%, respectively between May and November, while a decrease of up to 4.54 and 5.80%, respectively was found between December and April. The results showed that climate variability and land-use change have noticeable impacts on streamflow and sediment load, suggesting an adaptation plan for lake ecosystem conservation.

The feasible framework developed in this research would serve as a central approach to estimating streamflow, sediment load as well as other hydrological variables in poorly gauged basins. For a similar purpose, this methodology can be applied as well in other river basins globally.