氏　名	HO THI PHUONG
授与した学位	博　士
専攻分野の名称	環境学
学位授与番号	博乙第４５０６号
学位授与の日付	２０１９年　９月２５日
学位授与の要件	博士の論文提出者 （学位規則第４条第２項該当）
学位論文の題目	Synoptic transport modeling in the Ca River Basin, North Central Vietnam （ベトナム中北部カー川流域の物質輸送モデルに関する研究）
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学位論文内容の概要

The Ca River is the third largest in Vietnam and covers 27,200 km^2 (17,730 km^2, 65.2% in Vietnam). The trunk river is 531 km (the upper 170 km in Lao PDR). Since 1986, introduction of a market oriented socialist economy ‘‘Doi Moi’’ has resulted in a rapid growth of agricultural and industrial productions without explosive urban growth and uncontrolled rural exodus. However, land-use activities including timber harvest, livestock grazing, agriculture and urbanization have been changing rapidly. That may be the primary causes of altered flow regimes and material budgets. Several dams have been built for multiple purposes of flood and drought control, electrical power generation and irrigation at upstream since 1995. Human modification of natural processes may disrupt dynamic equilibrium between water and sediment fluxes in the natural stream. The aim of the dissertation thesis is to examine the degree of human-induced alteration of natural flow regime and the material budgets by using a synoptic model consisting of runoff model, with the regime and resistance laws of the river basin.

The Hieu River is the largest tributary where cumulative anomaly and Pettitt tests were done to ascertain turning points in annual rainfall and discharge in 1962–2014. The results of statistical analyses to reveal a breaking point in 1982 for rainfall and in late 1970s and late 1990s for discharge. A storage-type runoff model was used to trace runoff processes of different periods corresponding to detecting changing points. The results confirm that a two-tank model with monthly meteorological data is appropriate for the Hieu River. The difference between hydrographs improved by using monthly varied rain factors. A comparison between observation and calculation revealed a drastic decrease from 1999 to 2014. Discharge loss in the downstream was approximately six times higher than that in the upstream basin, which is potentially due to reservoir construction and intensive water use for agricultural and residential purposes.

The regime laws of hydraulic properties at Dua and Yen Thuong along the main river were combined into sediment transport as power functions of discharge with exponents of 1.46–1.85 using Manning roughness coefficient and the settling velocity to simulate the suspended sediment load. The Nash-Sutcliffe efficiency, percent bias, and the ratio of the root-mean-square error to the standard deviation of measured data were used to evaluate calibration process in a pre-dam period (1994–2004) and for validation in a post-dam period (2005–2014). Effects of dam construction include changes in relationship between the roughness coefficient and the particle size. Observed sediment load decreased by 20–40% after dam construction at both the stations. Power functions with exponents of 0.968 and 0.992 were used for the dissolved solid load to integrate long-term annual total dissolved solids (TDS) at Dua and Yen Thuong, respectively. After dam construction, average total suspended solids TSS-to-TDS ratio decreased from 3.0 to 2.3 at Dua and from 4.1 to 2.2 at Yen Thuong.

This study also investigates chemical composition of dissolved matters in the river basin. Water samples were collected during the year from August 2017 to July 2018 at three stations along the river. Carbonate weathering is the dominant process controlling water chemistry of the river. Bicarbonate and calcium are dominant chemical species, accounting for 84.4% and 62.0% of the total anionic and cationic charge, respectively. The average dissolved-solids concentration is 144 mg/l and generally decrease from the upstream to downstream, resulting in a decrease of major ions in the downstream. The variation of major chemical ions and suspended solids concentration with discharge was also investigated. As a result, major chemical weathering products behave chemo-statically, with increasing discharge in the upstream. However, the dilution behavior of solutes is shown in mid- and down-stream. The nitrate and phosphate ions show a constant to increasing concentration stream-wise, indicating additional sources of organic degradation and human activities. There is a primary evidence that water storage for reservoirs has impacted on a variation of suspended solids and dissolved solids in the Ca River.

論文審査結果の要旨

降水量と蒸発量（または気温・相対湿度）を与えるタンクモデルの計算流量で位数則・レジム則・抵抗則・キルヒホフ則，水位・流量関係，溶存・懸濁態負荷量を評価しながら水理・水文・水質因子を順次加えていく形で以下のように論文が構成されている。この流れに従って，審査を行い，各章の独自性，新規性，実用性，信頼性，全体の整合性を検討した。

二段タンクモデルを月単位で計算する方式は一般的ではないが，現存する半世紀間の水文資料を最大支川ヒュー川に適用し，降水因子を月毎に変えてハイドログラフを改良，結果的に長期流況の変化の要因として，森林伐採とそれに続くダム建設の人為的影響（水収支縮小や渇水による森林被覆率の変動）を引出すことに成功した。またパラメター最適化の統計ルーチンを付加し総観モデルを更新した（参考論文１）。ダム建設の結果，河道マニング粗度係数と流送土砂の粒径の関係が変化し，中流二地点の流砂観測値はダム建設後20~40％減少した。両地点はSSとともに，幅・水深・平均流速の流量依存（レジム則）が蓄積され，これに基づいて浮流砂式が求められ，既存公式と合致する結果が得られた（参考論文３）。炭酸塩風化は本流域の水文化学的な支配過程であり，風化生成物は上流域で静化学的に振舞うが，中・下流域では希釈効果がみられる。ただ中・下流域の栄養塩濃度で電導度も経年的に増加傾向を示す。全溶存物（TDS）の変動も貯水池の貯留効果によるが，流下遅延による懸濁・溶存濃度比に変化をもたらし，流下方向に一定か増加的なイオン濃度は，有機物分解や人間活動に伴う栄養塩の豊富さを反映する。これらの知見のうち三地点におけるイオン濃度の通年観測値は本研究の成果の一つである。今後貯水池の富栄養化が進行すれば，これらの動向を注視していく必要がある（参考論文２）。

以上，本研究は流量や物質輸送における人間活動の影響に言及しうる総観モデルの基礎を確立，評価基準としたダムの影響評価についても，実用化に向けて十分な展望をもたらしたと評価でき，河川流域における流域・水資源管理の在り方に寄与する点が少なくない。

以上のことを総合的に判断し，この学位審査の結果を合と判定した。