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論文題目	Impacts of Future Climate Change in Water Resources Management at the Chao Phraya River Basin, Thailand （タイ国チャオプラヤ川流域の水資源管理に及ぼす気候変動の影響）		

（論文内容の要旨）

In the heart of Thailand, food and water resources always rely on the Chao Phraya River Basin (CPRB) due to the characteristics of the basin and appropriate annual rainfalls of above 1,200 mm. However, those strengths can sometimes turn into risks caused by the impacts of climate change. Frequency of floods and droughts in the basin has risen year after year starting in 2005. Particularly, massive floods hit the basin for over three months in 2011. In reference to climate change, the Master Plan and the Free Pond Construction Project for non-irrigated areas were provided by the Thai government to mitigate floods and droughts. However, those plans do not consider how the changes in water resources management and future climate will influence the flow regime. This research aims to investigate the impacts of future climate change and adaptive water resources management on the flow regime, which is written in Chapter 1.

Chapter 2 provides knowledge and peer-review information from existing literature as well as opens necessary discussion for research methodology. Pros and cons in order to select hydrological model, climate change approaches, pond management model, and reservoir operation model have been reviewed.

In Chapter 3, the author has applied the Hydrological Simulation Program-Fortran (HSPF) model based on the characteristics of the CPRB. The author also evaluated the effectiveness in preventing the 2011 floods by two possible adjustments (*i.e.,* daily release storage ratios (r) and the timing of water release) for two large-scale dams. This chapter also dealt with the scenarios of detention ponds, including the proposed retarding basins by the Thai Master Plan and the suggested new detention ponds. The results have highlighted that the appropriate ratios (r) for dam operation were in the range of 0.007-0.008 during the mid-rainy season (July-August) and 0.001-0.002 during the end of the rainy season (September-October). Ninety-four percent of overflow volume, consequently, can be attenuated *via* the integrated watershed management, combining both advisable scenarios of dam operations and detention ponds.

Chapter 4 was aimed to build up approaches for the post-processing climate change data (interpolation and bias corrections) using the database for Policy Decision Making for Future Climate Change (d4PDF). In order to predict extreme rainfall, the gamma distribution combined with a Generalized Pareto Distribution (Gamma & GPD) and the gamma distribution methods were applied to the rainy and dry seasonal datasets, respectively, in the bias correction approaches. This chapter also included trends of the post-processing d4PDF outputs with three ensembles (MI, MP and MR) of two periods (2051-2070 and 2091-2110). The reduction of the annual rainfall was indicated at downstream of the Ping River Basin in the Upper CPRB. For the extreme rainfall, the

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maximum annual rainfall above 3,000 mm/year was projected by three ensembles.

Since so far the specific pond capacity for the Free Pond Construction Project for non-irrigated areas was planned and started without considering the local conditions, water requirement, or prevention of floods and droughts, Chapter 5 has achieved to construct a pond management model driven by the water requirement model, the water budget model and the economic model. With a view to estimate pond capacity considering long-term impacts, the future climate data were also included. At greater than 80% of pond reliability, the minimum capacity of future ponds was suggested to be in the range of 1,000-3,000 m^3 with a depth range of 2-4 m. The maximum pond capacity should be over 5,000 m^3 with a depth of more than 4 m to protect future overflows.

Since the reservoir operation of the two large-scale dams played a significant role in the flow regime, Chapter 6 has constructed a reservoir operation model using the Adaptive Neuro-Fuzzy Inference System (ANFIS). In order to achieve an effective reservoir operation for flood prevention, the simulated reservoir water releases by adding the daily release storage ratio (r) of 0.006 during the mid-rainy season and applying the ratio (r) of 0.001 during the end of the rainy season were designed for the additional reservoir operation. This chapter also included the future d4PDF climate data. The future reservoir discharges at the mid of the rainy seasons were about 500-2,000 million cubic meters (MCM) per month and less than 400 MCM per month at the end of it. During the rainy seasons, about 6,000-8,000 MCM would be stored at both dams to support water for the next dry season.

In Chapter 7, the author investigated the impacts of the future climate change, reservoir operations, and the pond management on the flow regime. The annual maximum daily flow relevant to non-exceedance probability was used and analyzed the flood frequency. Because of impacts from climate change and reservoir discharge, the extreme daily flow could be in the range of 5,500-6,800 m^3/s at the CPR origin. Related to the annual rainfall reduction in the downstream of Ping River, the period up to 80 days might have no flow as well as a water shortage at mid-stream of CPR. One of the most benefits within future impacts of pond management was the reduction of extreme peak flows at the end of rainy seasons. Also, the mitigation of water shortage was projected during the low flow.

The final chapter summarized the important research findings as mentioned above. Since the timing change and the quantity increase of the annual maximum daily flow at the Upper CPRB were the undesirable impacts of pond management, the timing of pond water release should be considered more detail in further research. For future Thai government plans, the author has also suggested to increase the river capacities considering the results of annual maximum daily flow.

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（論文審査の結果の要旨）

タイのチャオプラヤ川流域（Chao Phraya River Basin: CPRB）では、今世紀に入ってから洪水と干ばつの発生頻度が増加している。特に、2011 年には、３か月以上にわたる大規模な洪水が CPRB を襲った。タイ政府はこれらの洪水や干ばつによる影響を緩和するために、「非灌漑地域における水資源管理のためのマスタープラン」を策定すると同時に、「貯留池造成プロジェクト」を立ち上げた。本研究では、これらの新たな水資源管理政策・プロジェクトでは十分な考慮・検討がされていない河川流況への影響を、将来の気候変動も踏まえて明らかにすることを目的とした。

本研究では、まず、CPRB の特性に基づく水文モデルを Hydrological Simulation Program Fortran (HSPF)を用いて構築した。構築した水文モデルを用いて、既設のプミポンダムとシリキットダム、および流域全体にわたって新たに造成される複数の貯留池による洪水・渇水緩和効果を検討・評価した。この結果、2011 年と同程度の降雨による河川氾濫頻度を 9 割以上削減することが可能なダムの運用方法と貯留池の位置、数、容量について提案することが出来た。

気候変動の影響については、CPRB の将来の降水量分布を予測するために、公表されている database for Policy Decision Making for Future Climate Change (d4PDF)に CPRB に合わせて補間・バイアス修正を含むデータ処理を適用して、CPRB の気候変動データを作成した。この結果、CPRB では、最大で 3,000 mm を超える年間降水量となる異常降雨が発生する地域が存在すると同時に、CPRB 上流ではわずか約 500～1,000 mm の年間降水量しか予測されない地域が存在することが明らかになった。

本研究で処理・作成した気候変動データを用いて、気候変動に適応するための２つの既設ダムと新たに造成する貯留池の運用方法について、モデルシミュレーションにより検討した。プミポンダムとシリキットダムの運用に、Adaptive Neuro-Fuzzy Inference System (ANFIS)を適用した結果、乾季に必要な河川水量を確保するために、両方のダムに合計で最低約 6,000～8,000X10^6m^3 の水量を貯留する必要があることがわかった。タイ政府が計画している「貯留池造成プロジェクト」では、貯留池が造成される各地域の地理・水文等の特性が考慮されていない。本研究で地域特性を考慮してモデルシミュレーションを実施した結果、それぞれの地域において貯留池の適切な数と容量を算出することができ、効果的な運用方法も提案することができた。

本研究の成果により、CPRB の 2 つの既設ダムや新しい貯留地の適切な造成と運用により、気候変動の影響による洪水や渇水の影響を最小限にすることが可能であることが明らかになった。これらの成果は、タイ政府が CPRB の水資源管理の将来計画を策定・実施するため必要不可欠なものであり、学術上、実際上寄与するところが少なくない。よって、本論文は博士（工学）の学位論文として価値のあるものと認める。また、令和 2 年 7 月 28 日、論文内容とそれに関連した事項について試問を行い、申請者が博士後期課程学位取得基準を満たしていることを確認し、合格と認めた。

なお、本論文は、京都大学学位規程第１４条第２項に該当するものと判断し、公表に際しては、当該論文の全文に代えてその内容を要約したものとすることを認める。

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