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博士論文審査結果報告
Doctoral Dissertation Defense Results

審査委員会を代表し、以下のとおり、当該学生が博士論文審査に合格したことを報告します。
On behalf of the Examination Committee, I am pleased to report that the student indicated below has successfully defended her/his dissertation.

政策研究大学院大学　　連携教授　　小池　俊雄
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プログラム名 Program	防災学プログラム Disaster Management Program	
学位申請者氏名（学籍番号） Name of the Candidate (ID)	Mr. Illangasingha Sanjeewa Punsiri Bandara (DOC21132)	
論文タイトル/ Dissertation Title	A Holistic Analysis System to Support Water Resource Policy Decisions under Climate Change	
(和訳/ English Translation)	（ 気候変動下における水資源政策決定支援のための包括的な解析システム ）	
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1. 論文概要と判定理由

1. Summary of the Dissertation and the Committee's Evaluation

To improve resilience to floods and droughts under climate change, this dissertation maximizes the use of existing knowledge and introduces new types of science and technology that serve broad and collective societal needs. The background and broad research framework are described in Chapter 1. Chapter 2 clearly explains the rationale for conducting this research in Sri Lanka.

In Chapter 3, this dissertation proposes five principles for using General Circulation Models (GCMs) at local and regional scales to overcome the model uncertainties in decision-making. According to these principles, this dissertation examines historical and projected precipitation from 44 GCMs, calculated under the Representative Concentration Pathways (RCP) 8.5 scenario to establish a decision support system based on the degree of confidence for nine different major river basins in tropical Sri Lanka as a case study, considering regional, geographical, and temporal variability.

In Chapter 4, the Water and Energy Budget - Rainfall-Runoff-Inundation (WEB-RRI) model, which can continuously simulate both low and high flows without re-initialization and re-tuning, was used in climate change impact assessments of 8 basins in tropical Sri Lanka. The model produced comprehensive hydrological outputs, which were summarized using hydro-meteorological indices to express water availability and agricultural resilience under climate change. Policy makers can use these indices to inform strategic water management decisions, thereby increasing agricultural resilience. The mapping and color-coding approaches developed through this dissertation allow for more effective communication of adaptive water allocation and disaster risk reduction initiatives to a broader audience.

The results of the analysis in Chapter 4 indicated that the northern basins are facing water stress trends in some seasons, while flood damage projections are increasing throughout the 21st century. In Chapter 5, the Water Evaluation And Planning (WEAP) model was used to evaluate the water supply to demand locations in the northern areas for future flows. The inter-basin water sharing system developed in this country with a long history was evaluated for future flow projections. It was found that without the system, these northern basins would be severely affected by drought most of the time, while the basins could be fully and sustainably supplied. It was also suggested that there would be further economic benefits from expanding the system. This demonstrates that water-sharing systems can increase societal resilience even under climate change scenarios.

The comprehensive framework developed by this dissertation, implemented in diverse tropical multiple key basins of Sri Lanka, can be applied globally. This dissertation demonstrates that addressing the effects of climate change cannot be addressed by individual systems alone. Instead, a successful approach requires an integrated system design that includes inter-basin water sharing. The Examination Committee highly appreciates this dissertation not only as a case study, but also as a research with scientific value to support policy making for water-related disaster risk reduction and adequate water resources management under climate change.

2. 論文の内容（手法や結論など）と学術的貢献

2. The Dissertation's Findings, Methodologies, and its Academic Contribution

This dissertation has resulted in the following unique research achievements to support policymaking aimed at enhancing resilience to water-related disasters, which are becoming more severe and frequent due to climate change, and establishing appropriate water resource management practices.

Uncertainties in the output of General Circulation Models (GCMs) as a basis for consensus building to reduce greenhouse gas emissions to mitigate global warming have been improved at the global scale, but remain significant at regional and local scales. Therefore, from a policy maker's perspective, this dissertation proposes the following five principles for the use of GCMs in policy making:

1) The climate models used for decision-making should accurately represent the current regional climate;
2) When using GCMs at the regional or local scale, downscaling and bias correction should be implemented;
3) The climatic sensitivity of climate models should be identified;
4) The disparities in outcomes among climate models should be understood; and
5) Climate models should be able to address the diversity environment.

Following these principles, this dissertation examines historical and projected precipitation from 44 GCMs, considering regional geographic and temporal variability. It presents scientific findings for establishing an evidence-based decision making support system for 9 diverse major river basins in tropical Sri Lanka. The output of each GCM selected and subjected to downscaling and bias correction by this study captures the current climate characteristics at a basin scale. This dissertation also quantifies the climate sensitivity of each GCM, which varies geographically and temporally. This dissertation investigates changes in seasonal precipitation due to climate change by identifying the range of their uncertainties. The results are expressed through simple, thorough climate analysis charts to contribute to communication between the scientific community and the key public who make decisions.

In order to translate the information on precipitation changes due to climate change into information on extreme events of floods and droughts and water resources under normal conditions, this dissertation presents the following five sets of guiding principles:

1) Reliable GCM outputs should be utilized as inputs to hydrological model;
2) Utilize a seamless-capable hydrology model that provides direct or relevant main outputs such as discharge, energy and water flux, soil moisture, groundwater, and inundation;
3) Identify climate change features using various hydro-meteorological indices;
4) Use the results of the hydrology model to recognize key climate change phenomena, such as floods or droughts and future impact projections; and
5) Ensure that hydrological models are capable of addressing diverse environments.

Following these guiding principles, the Water and Energy Budget - Rainfall-Runoff-Inundation

(WEB-RRI) model, which can simulate both low and high flows without re-initialization and re-tuning, is used to assess the impacts of climate change in tropical Sri Lanka by inputting the results of the GCM analyses. In order to assess the impact of climate change on water availability and to inform strategic water management decisions and thereby increase agricultural resilience, this dissertation summarizes comprehensive hydrological model outputs by using hydro-meteorological indices along with analyses of groundwater variations, soil moisture, water availability, and extreme flows (both low and high). In addition, the mapping and color-coding approaches developed in this dissertation allow for more effective communication of adaptive water distribution and disaster risk reduction initiatives to a broader audience.

In addition, this dissertation focuses on the inter-basin water sharing system, which is a historical asset in the target area, and quantifies the function of the system in adapting to climate change and the potential for improving disaster resilience and supporting sustainable development in the area through system expansion.

The major river basins in Sri Lanka, which are the focus of this dissertation, are distributed in the semi-arid to tropical zones, with a distinct seasonal and spatial distribution of rainfall due to the two monsoons. This study develops a holistic system for this highly diverse region and demonstrates its robustness through validation. The results of this study are not limited to a case study of a single region, but are considered research findings that can be applied globally. In addition, this dissertation has quantitatively demonstrated the effectiveness of an inter-basin water sharing system, which is considered to be an important adaptation measure to climate change, although it is usually difficult to consider such measures due to issues such as water rights.

As described above, this dissertation presents two sets of principles and transforms a set of GCM outputs, including non-negligible uncertainties at regional and local scales, into useful information for water-related disaster risk reduction and water resource management under climate change, and presents not only adaptation measures to climate change but also concrete measures to support sustainable development. This dissertation is highly commendable for developing a comprehensive evidence-based decision making support system that links cutting-edge scientific knowledge to concrete actions in the region.

3. 審査員からの主要コメントおよび修正内容

3. Comments by the Examiners and the Revisions Made

(1) The review of the literature and the discussion of the study's contributions to the literature could be presented more clearly and more effectively. It would benefit readers if they appear in the introduction in a more organized fashion.

Response: I have added the literature review to each chapter, in addition to the overall introduction chapter. Each chapter specifically discusses a critical issue separately. However, I acknowledge the importance of connecting these chapters more clearly. I also recognize that the contributions of the study need to be introduced in the first chapter. I revised the introduction based on your feedback, including the relevant part

of the literature review and the contributions of the study.

(2) I would suggest that he would better put some more introductory information into each section of his presentation, particularly in terms of the configurations of simulation and data analysis.

Response: **I** revised the dissertation's relevant chapters to clearly state the problems and key solutions at the beginning of each chapter, and briefly describe the corresponding conclusions as a separate paragraph at the end of each chapter.

(3) Why do some models show an increase in some variables while others show a decrease? Additionally, in the near future (NF), some models predict an increase in some variables, while in the middle future (MF), they predict a decrease, and in the far future (FF), some variables show another increase. What are the reasons behind these variations?

Response: Uncertainty in GCM projections leads to varied outcomes due to several factors. Each GCM has a unique model structure and parameterization, and the timing and magnitude of feedback mechanisms can vary, contributing to differences in projections. Additionally, calibration and validation parameters differ among models, affecting the projections. These aspects are discussed in detail through sensitivity and uncertainty analyses in section 3.4.5.

(4) Others (Appropriate responses and revisions to each comment have been confirmed by each Referee and the Main Referee)

1) This dissertation includes the student's own earlier work published in the Journal of Hydrology. This should be properly declared and cited in the dissertation.
2) There are a number of figures and tables that do not provide the sources of their data. The student needs to provide the sources of all figures and tables, including those using data produced by himself.
3) Comments on each Chapter
   A) Abstract:
      i) List the major issues/ obstructions to tackling climate change in many countries
      ii) Describe the originality of this study
      iii) Describe the advantages of the proposed method
      iv) Applicability of the developed approach in other regions around the world
   B) Introduction: Too lengthy and more general. Revise it by including scientific and practical challenges, previous achievements and gaps, and your new approach
   C) Research Framework: Better move the description of previous studies to the introduction, and describe your proposed methodology in detail
   D) Each chapter introduction: Too lengthy and better shorten them
   E) Figure and table: Most of them are small and difficult to read in a printed form, revise them,

F) Descriptions of study area and policy proposal: In each chapter are repeated, better group them and summarize them comprehensively

G) Implementation of research outcomes: Describe the short- and long-term strategies