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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　　大原　美保
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防災学プログラム 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)	Ballaran Vicente Jr. De Guzma (DOC21131）	
論文タイトル/ Dissertation Title	Developing an Integrated Approach for Optimizing the Climate Change Impact on Water and Agriculture Nexus in the Philippines: The Case of Pasig-Marikina River and Laguna Lake Basin	
(和訳/ English Translation)	（フィリピン共和国での水と農業の連鎖関係における気候変動影響の最適化に向けた統合的アプローチの構築：パッシグ・マリキナ川・ラグナ湖流域でのケーススタディー）	
学位名（専攻） Degree Name	博士（防災学） Ph.D. in Disaster Management	
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1. 論文概要と判定理由
1. Summary of the Dissertation and the Committee's Evaluation

Climate change is increasingly recognized as a critical factor affecting water resources and agricultural productivity globally. In the Philippines, a nation highly vulnerable to climatic shifts due to its geographical location, the impacts are particularly pronounced. The Pasig-Marikina River and Laguna Lake Basin, a vital area for both water supply and agriculture, faces significant challenges as a result of changing climate patterns. The interconnectedness of water resources and agriculture necessitates a comprehensive approach to manage and mitigate these impacts effectively. This study aims to develop an integrated approach to optimize the impact of climate change on the water and agriculture nexus under projected climate change scenarios in the Pasig-Marikina River and Laguna Lake Basin by employing high-resolution climate models, hydrological simulations, and agricultural simulation and productivity assessments.

The dynamically downscaled and bias-corrected MRI-AGCM 3.2S super high-resolution Global Climate Model (GCM) was utilized and input-forced into the Water and Energy Budget-based Rainfall-Runoff-Inundation (WEB-RRI) hydrological model. The GCM simulations were performed for both past (1979–2003) and future (2075–2099) climate RCP 8.5 scenario (a severe or business-as-usual scenario) to analyze the projected shifts in discharge and lake levels within the basin. The results indicate future climate shift causes nearly tripled flood frequency, prolonged maximum inundation duration, and substantial increases in both maximum flood extent and depth, particularly affecting low-lying areas within the basin, especially the rice fields. In linking the generated past and future climate scenarios to agricultural production, the calibrated Crop Growth Simulation Model (SIMRIW) was coupled with the WEB-RRI model. Results show that rice production will be significantly affected, with a potential decline in yields without countermeasures. Finally, based on these results, future strategies combining structural and non-structural countermeasures including recommendations such as construction of river control structures, use of pump stations, adaptive cropping strategies, comprehensive climate policies, and training programs for capacity building were proposed.

Doctoral dissertation defense of Mr. Ballaran Vicente Jr. De Guzma was held on June 24, 2024 at GRIPS. Following to the comments from the Doctoral dissertation review committee at the defense, the dissertation was revised and submitted again to the committee on July 19. Finally, the Doctoral dissertation review committee evaluated that this study verified the integration of hydro-agricultural models and advanced

agricultural monitoring is beneficial in optimizing the impact of climate change on the water and agriculture nexus. After further minor revision, the improvement of dissertation work was completed and submitted on August 20, 2024.

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

The dissertation consists of 8 chapters. Chapter 1 provides a brief background of the study, along with its objectives and a description of the research framework. The usual method for evaluating the impacts of climate change on flooding and agricultural production involves using computer models. Typically, hydrological models and crop models are handled separately, as demonstrated in the past works. However, hydro-agricultural models are important in the context of climate change by integrating climate data with agricultural and hydrological processes to assess the impact of climate variability on water resources and crop production. This study aims to develop an integrated approach to optimize the impact of climate change on the water and agriculture nexus under projected climate change scenarios in the Pasig-Marikina River and Laguna Lake Basin by employing high-resolution climate models, hydrological simulations, and agricultural simulation and productivity assessments.

Chapter 2 contains a description of the study area. The Pasig-Marikina River and Laguna Lake Basin is the seventh largest basin in the Philippines with a catchment area of 4,108.74 km2 and contains the largest living lake (Laguna Lake) in Southeast Asia. It consists of 29 sub-basins, with 22 of them, referred to collectively as the Laguna de Bay basin, draining into Laguna Lake. Meanwhile, the runoff from the remaining seven sub-basins of the Metro Manila rivers flow into Manila Bay. The basin covers the National Capital Region, a small portion of the province of Bulacan, and a large part of the CALABARZON Region composed of the provinces of Cavite, Laguna, Batangas, Rizal, and Quezon.

Chapter 3 details the methodology. Overall framework and details of each model were explained. The framework involves super high-resolution, bias-corrected, dynamic downscaling of a global climate model, enabling the projection of absolute changes in future rainfall. Integrating this with a hydrological model, capable of predicting and simulating inundation while considering the water and energy balance of the system,

ensures more reliable climate projections and enhanced flood modeling. This approach provides soil moisture data which, when coupled with crop modeling, offers a better assessment of agricultural production in terms of yield. This integrated approach leads to optimize the impact of climate change on the water and agriculture nexus of the Pasig-Marikina River and Laguna Lake Basin and suggest possible results-based policy recommendations.

Chapter 4 examines the climate change effect on the discharge and lake level of the Pasig-Marikina River and Laguna Lake Basin, integrating the Global Climate Model and Hydrological Model. The dynamically downscaled global climate model was used to drive a hydrological model framework aimed at analyzing the projected shifts in discharge and lake levels within the Pasig-Marikina River and Laguna Lake Basin. The GCM simulations were performed for both past (1979–2003) and future (2075–2099) climate RCP 8.5 scenario (a severe or business-as-usual scenario) within the basin. As hydrological model, the Water and Energy Budget-based Rainfall-Runoff-Inundation (WEB-RRI) model, which integrates processes related to water and energy budgets, multi-layer soil moisture dynamics, land-vegetation-atmosphere interactions, and two-dimensional lateral water flows and flood inundation was applied. The model employs a one-dimensional diffusive wave model for rivers and a two-dimensional diffusive wave model for slopes. The results indicate an impending climate shift in the future, characterized by several key findings: an increase in maximum daily discharge, attainment of maximum mean monthly discharge a month earlier, significant rises in mean monthly discharge observed in four specific months, elevation of maximum daily lake levels, nearly tripled flood frequency, prolonged maximum inundation duration, and substantial increases in both maximum flood extent and flood depth, particularly affecting low-lying areas within the basin.

In Chapter 5, the coupled hydro-agricultural model is utilized to assess the climate change impact on the water and agriculture nexus in the basin. To investigate the impact on agricultural production, a crop model (SIMRIW) was coupled with the hydrological model (WEB-RRI). SIMRIW is a streamlined process model designed to simulate the growth and yield of irrigated rice in response to weather conditions. The results indicated that increased rainfall during the wet season might cause a decrease in rice production in low-lying and coastal areas due to flood damage. Meanwhile, irrigation during the dry season will remain crucial as rainfall and lake discharge are projected to remain relatively unchanged during this period. Proper planting dates are also critical, as deviations can significantly affect rice yield.

Chapter 6 focuses on improving the estimation of rice crop damage from flooding events using open-source satellite data and UAV image data. For agricultural monitoring, the use of multispectral cameras mounted on UAVs has proven highly effective in precision agriculture applications, particularly for monitoring rice paddies. These cameras provide detailed results with higher spatial resolutions, capturing comprehensive information about small areas. However, when assessing larger areas and conducting damage assessments, satellite imagery emerges as a valuable alternative. Fast and reliable estimation of rice crop damage was achieved using satellite-derived information.

Chapter 7 integrates and optimizes the results from the previous chapters to develop results-based policy recommendations. The integration of high-resolution climate models with coupled hydro-agricultural models and advanced tools such as UAVs and satellites has proven beneficial in optimizing the impact of climate change on the water and agriculture nexus of the Pasig-Marikina River and Laguna Lake Basin. The proposed strategy integrates a combination of structural and non-structural countermeasures including recommendations such as construction of river control structures, use of pump stations, adaptive cropping strategies, comprehensive climate policies, and training programs for capacity building. These measures represent a comprehensive approach to mitigating the impacts of climate change, promoting both immediate and long-term benefits. The final chapter, Chapter 8, presents the conclusions of the study, including its limitations and suggestions for future work.

In this study, the integration of high-resolution climate models with coupled hydro-agricultural models and advanced tools such as UAVs and satellites has proven beneficial in optimizing the impact of climate change on the water and agriculture nexus of the Pasig-Marikina River and Laguna Lake Basin. These findings hold crucial implications for policymakers, water resource managers, and researchers striving to develop climate-resilient strategies amidst evolving hydrological conditions.

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

The dissertation was fully revised based on the comments listed below.

<Overall>

- Mr. Ballaran Vicente Jr. De Guzma has completed end-to-end approach of the climate change impact study from data to policy recommendation. The logic of the study process is clear although some of the chapters should be strengthened by produced evidence and supplementary explanation of the works that have been done.
- Review of the precedent studies should be added to clarify uniqueness, originality, and validity of the study.
- Previous research, gaps, objectives and novelty of the research should be clearly described with appropriate references.
- The linkage among the major components of the research framework needs to be described clearly and logically.
- The content of the doctoral thesis is very meaningful and sufficient for obtaining a degree. However, there are some points that are insufficiently considered. The figures and tables were not sufficient to support the recommendations and required major revisions.
- The introduction chapter needs a summary of the new findings of this research. The main contribution of this research would be combining the hydrological and crop models to provide a more reliable assessment of climate change's impact on agriculture. The author should argue that his model is better than existing (not integrated) models from several viewpoints, referring to the literature.

＜Each simulation model＞

- As this study focus on the linkage between climate-hydro-agri model, flood damage needs to be more analyzed in detailed way by using coupled model.

＜Policy Recommendation＞

- The recommendation part on structure measures should be fortified by additional explanation on validity of the methods based on existing data and facts.
- Policy recommendation is not fully linked with analysis results. Please show the difference of impact with/without policy. Then, the effect of implementation of proposed policy will be fully explained.
- Chapter 7, Policy Recommendations, includes a summary of the results. However, the description is too

short to provide the key to the research. It often just gives figures or expressions without giving enough explanation. Give a detailed report on the findings in the text.