（ 続紙 1 ）

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論文題目	Study on evapotranspiration and canopy photosynthesis during and after rainfall in a Japanese cypress forest（降雨中・直後のヒノキ林における蒸発散および群落光合成に関する研究）		

(Abstract of the thesis)

To reveal the mechanism and significance of canopy gas exchange during and after rainfall in temperate coniferous ecosystems, this study used the eddy covariance (EC) method in combination with an enclosed path gas analyzer to conduct the continuous ecosystem flux observation in a Japanese cypress forest within the Asia monsoon area for over 3 years. Then, the results were compared with model simulations to evaluate interception evaporation from the abaxial surface of the Japanese cypress leaf, the relationship between abaxial interception and wet canopy photosynthesis and canopy gas exchange during different periods after rain events ended.

Chapter 1 is a literature review, which demonstrates a research gap between leaf wetness and plant gas exchange. Concerns over the ecological function of wet leaves in terrestrial hydrological and carbon circulation are expressed in several studies in recent years. However, compared to the ecological value of fog-induced leaf wetness in tropical areas, the influence of rainfall-induced leaf wetness on wet coniferous canopy evapotranspiration and photosynthesis in the temperate area is less often evaluated. Few studies have investigated the possibility of abaxial interception of rainwater by conifers. Thus, how interception affects canopy evapotranspiration and photosynthesis, other than its contribution to evaporation from the wet canopy, remains unclear. Furthermore, the continuous variation of the dry canopy gas exchange immediately after wetness ended is seldom addressed by existing studies.

Chapter 2 describes the site and methodology of this study. The study site is a Japanese cypress forest (coniferous, evergreen) at Kiryu experimental watershed in Shiga, Japan. The EC method was used to measure the continuous ecosystem fluxes. Wetness sensors were used to measure the change in the canopy wetness. A soil-vegetation-atmosphere transfer (SVAT) multilayer model is explained, which was applied to analyze the latent heat flux (λE) and net ecosystem exchange (NEE) under different interception scenarios (Chapter 3 and Chapter 4).

Chapter 3 reports the results of investigation on regulation of wet canopy evapotranspiration, which suggest the occurrence of interception evaporation from both sides of leaves from the wet Japanese cypress forest canopy during rainfall and after different levels of rainfall. Observed λE of the wet canopy was compared with simulation results of the SVAT multilayer model with contrasting sets of assumptions as to whether interception evaporation happens only from the upper (adaxial) side of leaves, or from both sides of leaves. Both models showed a low λE during rainfall as the EC data did. The simulated λE during the canopy-wet period after rainfall indicates that the interception evaporation from both sides of leaves is more likely after heavy rainfall. However, for the

most frequent small rainfall events at this site, the abaxial surface may not be fully wet as the adaxial surface. Hence, some stomata remain open without being blocked by abaxial leaf wetness, resulting in low but significant CO_2 uptake by the wet canopy.

Chapter 4 reports the study on the influence of abaxial surface wet area ratio and leaf water storage capacity on wet canopy NEE simulation with the SVAT multilayer model. For the wet canopy during and after rainfall, the model overestimated CO_2 uptake when it assumed no abaxial interception in the simulation, but it underestimated CO_2 uptake when it assumed that the entire abaxial surface was wet. The multilayer model had the best prediction of the observed NEE when it assumed the wet area ratio of the abaxial surface being 50% both during and after rainfall. Thus, the results suggest that the abaxial surface of a Japanese cypress leaf is only partly wet to keep stomatal openness to maintain a low level of photosynthesis. Moreover, temporal trends of NEE showed that the wet canopy CO_2 uptake occurs during the post-rainfall canopy-wet period rather than during-rainfall period.

Chapter 5 focuses on the gas exchange of the dry canopy during different periods after wetness ended. This chapter explains the work using an expanded big-leaf model to estimate the canopy conductance (g_c) of the dry canopy at different timing after canopy wetness ended, *i.e.*, "0–3 hours after wetness ended", "3–6 hours after wetness ended" and "dry over 6 hours". The relationship between the gas exchange variables and the meteorological factors, including VPD (vapor pressure deficit) and R_n (net radiation), is discussed. Larger values of g_c were found in its relationships VPD and R_n during the first three hours after wetness ended. The results for λE were similar to that of g_c in spring and summer, while no clear difference was found for NEE in the relationships with R_n regarding the stages after wetness ended except in spring. Nevertheless, both average and summed-up NEE showed that CO_2 uptake during the first several hours after wetness ended was larger than the uptake during typical dry periods.

Chapter 6 summarizes the findings in the above chapters, which together reveal the mechanism of wet Japanese cypress canopy maintaining CO_2 uptake during and after rainfall, as well as the significance of wet canopy CO_2 uptake in the long-term ecosystem carbon balance, including the rainfall's contribution to improving dry canopy CO_2 uptake. These results contribute to future improvements to ecosystem carbon exchange models, in particular the effect of rainfall on forest hydrological and carbon circulation under the changing climate.

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（続紙　２　）

（論文審査の結果の要旨）

降雨による葉の濡れ乾きが、樹冠蒸発散および光合成過程に及ぼす影響を解明することは、湿潤地域の森林における水循環や炭素循環を明らかにする上で重要な課題であるが、直接測定の難しさから実態解明が進んでいなかった。本研究は、降雨中・直後にも高精度測定が可能なエンクローズドパスガス分析計を用いて、クローズドパス型渦相関法による群落スケールでの3年超のフラックス連続観測を行い、降雨中および降雨直後のヒノキ林において、降雨による葉面の濡れ乾きが樹冠蒸発散および光合成過程に及ぼす影響を定量的に明らかにしたものである。本研究の評価できる点は以下の通りである。

1. 樹冠スケールでの顕熱・潜熱・CO_2フラックス、微気象、および濡れセンサーによる樹冠内各層濡れ乾きの連続観測と、数値モデルを組み合わせた独自の解析手法を開発し、降雨中・直後のヒノキ林におけるガス交換に与える濡れ乾きの効果を評価した。
2. ヒノキ葉の背軸面は、向軸面に比べて水貯留量が少ないだけでなく面積も部分的にしか濡れず、気孔は一定の開口部を維持できることで、降雨時、および降雨終了直後の遮断蒸発時に、背軸面の乾いた部分で光合成活動が行われていることを示した。
3. 樹冠が乾いて遮断蒸発が終了し蒸散に移行した直後には、群落コンダクタンスが通常よりも大きく、気孔が開き気味になることにより、CO_2吸収量の向上に寄与することを明らかにした。

以上のように、本論文は、降雨による葉の濡れ乾きが樹冠蒸発散および光合成過程に及ぼす影響を独自の解析手法によって定量的に解明したものであり、森林水文学、森林環境科学、植物生理生態学の発展に寄与するところが大きい。

よって、本論文は博士（農学）の学位論文として価値あるものと認める。

なお、令和５年２月１４日、論文並びにそれに関連した分野にわたり試問した結果、博士（農学）の学位を授与される学力が十分あるものと認めた。

また、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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