東シベリアカラマツ林の水・二酸化炭素交換量と下層植生の役割

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Contribution of understory vegetation on net ecosystem exchange of water and CO_2 at larch forest in eastern Siberia

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This study investigated evapotranspiration and CO_2 exchange over a 10-year period (2004–2013) in larch-dominated forests in central Lena river basin, eastern Siberia. The forest ecosystem in this region is characterized by low precipitation, a short growing season, and extensive underlying permafrost. An unusually wet active layer during the warm season that was maintained from 2006 to 2009 was observed, after which the soil water close to the ground surface became dry but the deeper part remained relatively wet. Some mature larch trees in areas with poor drainage suffered because of waterlogging, whereas young birch and willow trees developed and grasses with water tolerance expanded. Fluxes from the whole forest were enhanced during wet years and decreased around 2007–2008, although soil water was retained at the depth at which the greater part of the larch roots occur. A similar but clearer tendency was observed in the canopy-scale biophysical parameters such as surface conductance and maximum photosynthesis rate. Particularly regarding evapotranspiration, changes in the surface conductance and the Bowen ratio indicate changes in response function of the forest ecosystem, although there was no clear trend in fluxes for which the variation is affected also by the atmospheric conditions. Fluxes from the understory layer, in contrast, showed a positive trend in CO_2 exchange (GPP and ER) and maximum photosynthetic rate. Although this layer always acted as a CO_2 source in terms of the seasonal average throughout the study period, the source strength weakened and became a temporary sink on dairy base in the early summer. Sufficient soil water would lead to growth of understory vegetation, and, simultaneously, the partial decline of the larch crown altered the environment inside the forest by increasing light and enhancing turbulent mixing. The decline in the larch contribution was compensated for by understory growth, resulting in a relatively stable whole-forest exchange rate at least during this study period. Interactions between larches and understory vegetation would support the resilience of this forest ecosystem and the carbon and water cycle under environmental variability.

環北極陸域のタイガ林のうち、東シベリアでは落葉針葉樹のカラマツ林が優勢する。ここでカラマツを中心とする植物は、短い夏季と年間 200-300mm と少ない降水量の条件下で生育するために凍土の融解水を利用する一方で、蒸発散を介して、この地域に特徴的な水循環の形成に重要な役割を果たしていると考えられる。永久凍土上のカラマツ林における森林ー大気間の水・CO_2 交換特性と環境変動への応答について明らかにすることを目的としてフラックス観測が続けられている。ヤクーツク近郊の観測サイトでは 2005-2006 年の記録的な多雨年の後、2006-2009 年にかけて土壌水分の増加、地温の上昇、活動層深さの拡大をもたらし、2007-2008 年には土壌水分過大となった地点でカラマツが枯死する現象が起こった。また、かつてはコケモモが卓越していた林床植生に草本性植物が増加すると同時にカンバやヤナギの中低層木の成長がみられ、下層植生の変化が進行した。2004 年以降の林内でのフラックス観測によると下層植生の CO_2 交換量（吸収量と放出量）と蒸発散量は観測期間を通して増加した。季節積算すると下層植生からは CO_2 の正味放出となるが，夏季日中の吸収量は増加した。観測サイト周辺の一部のカラマツの枯死や機能低下によりカラマツ層の寄与は減少するが，下層植生により補われて森林群落全体の水・二酸化炭素交換量は維持されていると考えられる。