氏名	KHUN VATHANA
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論文審査委員	（主査）准教授　佐々木　ノピア
	（副査）教授　辻　正次
	（副査）教授　二之宮　弘
	（副査）准教授　円谷　友英

学位論文の要旨

Southeast Asia is rich in tropical forests and biodiversity but rapid deforestation and forest degradation have accelerated climate change and threatened sustainable development in the region. The issue of reducing deforestation and forest degradation (REDD+) has become a central theme of the United Nations Framework Convention on Climate Change (UNFCCC) negotiations because of its ability to mitigating climate change and achieving sustainable development. However, only a handful of studies exist so far on this important issue that are suitable to inform the debate with estimates of carbon stocks and emission reductions or removals as a result of REDD+.

This research attempts to analyze the potential emission reductions and removals and cumulative carbon fluxes due to selective logging in Southeast Asia for a 35-year period under the REDD+ scheme. This study starts by developing land use change and forest harvesting models that are used to estimate carbon stock changes in natural forests and forest plantations in Southeast Asia. Study results suggest carbon emissions from deforestation and forest degradation of natural forests were 1865.1, 1611.4, and 1300.4 $TgCO_2$ $year^{-1}$ between 1990 and 2000, 2000 and 2010, and 2015-2050, respectively. With a hypothetical carbon project of 35 years beginning from 2015, carbon emission reductions were estimated at 817.6 $TgCO_2$ $year^{-1}$, of which about 10% was from reducing forest degradation. Carbon removals due to increase of forest plantations were 76.3 $TgCO_2$ $year^{-1}$ but the removals could be much higher depending on definition on the eligibility of forest plantations. Summing up together, about 893.9 $TgCO_2$ of carbon credits could be achieved from implementing carbon project in Southeast Asia or about US $6.6 billion annually between 2015 and 2050 if carbon price in 2012 is used. In addition to reducing emissions, there are other benefits from carbon project implementation. This study suggests that REDD+ has great potential for reducing carbon emissions and enhancing carbon stocks in the forests. Without financial incentives, carbon project would not happen and therefore climate change will continue to threaten future development.

In addition, selective logging in Southeast Asia also contributes cumulative carbon fluxes. Selective logging creates a large amount of wood residues in forests in addition to producing a small amount of sawn-wood for use as source of construction materials. Cumulative carbon fluxes were analyzed between 2015 and 2050 under two scenarios, namely conventional (CVL) and reduced-impact logging (RIL). Study results suggest that CVL produced about 146.6 (±5.4) million m^3 annually. Logging created annual carbon fluxes of about 0.23, 0.23, 0.20, 0.69, and 0.15 MgC ha^{-1} $year^{-1}$ in sawnwood, wood wastes at sawmills (SWW), wood product wastes due to logging damages remained in the forests (WPW), branches and top logs (BRA), and belowground dead root (BLD), respectively. Cumulative carbon fluxes were estimated at 281.0, 506.6, and 87.4 TgC $year^{-1}$ in sawnwood, onsite (WPW, BRA, BLD), and offsite (SWW) pools, respectively. Except in SW, cumulative carbon fluxes in onsite and offsite pools showed a decline trend in about 10 years after logging. Switching from CVL to RIL could increase fluxes in sawnwood 60% higher than that under CVL, while reducing fluxes in short-lived onsite and offsite wood residues. Not only RIL can increase carbon fluxes in sawnwood, it can also increase production of sawnwood and retain more carbon in standing forests. Selective logging can create huge carbon fluxes in various wood components. Depending on carbon accounting methods, these fluxes could be used to offset carbon emissions from deforestation and forest degradation. Including carbon fluxes (credits) in sawnwood in climate change mitigation options would provide incentives for better utilization of harvested wood products and management of tropical forests. Otherwise, destructive logging and careless use of harvested wood will continue unabated. Providing incentives for carbon offset in harvested wood products will also stimulate the development of wood processing technology, which will eventually result in more sawnwood production and more carbon storage in harvested wood products, while retaining more carbon in standing forests.

From this study, it suggests that reducing deforestation and forest degradation has huge implications for climate change mitigation and sustainable development. Improved management of natural forests through the adoption of appropriate management system such as the use of reduced-impact logging would enhance carbon stocks in the forests and maintain or increase timber production for economic development and job generation. It is important that REDD+ be included as a climate change mitigation option and financial support for good forestry practices be made available continuously either through mandatory or voluntary markets or other form of payments. There are however limitations to this study. Prediction of future deforestation and forest degradation is difficult to validate because future development and political uncertainty in developing countries are unpredictable. Therefore, findings in this research should be used as indicative. In addition, deciding initial carbon stocks and illegal logging strongly affect the amount of timber to be harvested and other wood components. More forest inventory data are important for determining initial carbon stocks in the forests in order to reduce uncertainty that would affect overall estimation of carbon emissions from deforestation and forest degradation. Rate of illegal logging is difficult to determine because of the large area of tropical forests and this rate is affected by many factors such as political stability and demand for timber production. It is recommended revisions to initial carbon stocks and rate of illegal logging be revised in future study when more data become available. To encourage utmost use of harvested timber, future climate agreement should consider cumulative carbon fluxes as carbon credits that can be used to generate additional incomes while protecting tropical forests.

論文審査の結果の要旨

地球温暖化の1つの原因に発展途上国でおきている森林減少・劣化による炭素排出がある。森林減少・劣化を削減するためには、経済支援が必要となる。現在の経済支援の体制では、森林減少・劣化の削減による炭素排出削減量に応じて、支援されると決まっている。しかし、この炭素排出量及び排出削減可能な量についての測定方法に関する研究は少ない。本論文は、東南アジアの森林を対象として森林炭素蓄積、森林減少・劣化による炭素排出量と削減可能な量の測定方法を研究するものである。

第1章では、東南アジアにおける地球温暖化と森林減少・劣化による炭素排出とその炭素排出測定問題を解決し、本研究課題及び研究目的を述べた。

第2章では、森林減少・劣化による炭素排出量を測定した先行研究の多くは、森林減少によるグローバルレベルでの測定であり経済支援には活用不可能であると判明した。

第3章は研究方法で、まず生産林、保護林及び人工林の土地利用変化モデルを開発し、気候変動に関する政府間パネル(IPCC)の手法を参考しながら、各地上部、下上部、リターと枯死木の炭素蓄積を測定する森林炭素ストックモデルを開発した。これらにより、東南アジアにおいて森林炭素蓄積を測定できた。さらに、森林伐採後の炭素フラックスの測定モデルを開発し、森林減少・劣化の要因を削減するための対策方法を導入し、森林減少・劣化削減による炭素排出削減可能量の測定ができるようになる。そして、炭素排出削減量に応じて、地域レベル経済支援の対策方針が決めることが可能となる。

第4章は、研究成果及び議論である。国際支援がない場合、東南アジアにおいて1990年から2050年の問、年間約156万haの森林が減少し、炭素排出量は13.6億万tCO2(約20%は森林劣化からの排出量)であると測定ができた。$1.2－$8.4/tCO2の国際支援がある場合は、年間約8.2億万tCO2の炭素排出量(2013年度日本全国温暖化ガス排出量の約58%)が削減される。または人工林増加及び伐採された木材フラックスによるそれぞれ約9.3千万tCO2と1千万tCO2の吸収量が増加すると判明した。

第5章では、研究成果である森林減少・劣化の削減及び人工林と炭素フラックスによる、炭素排出削減量は温暖化防止に十分影響があるので、国際支援を得るため東南アジアで適切な対策を導入しなければならないと結論と付けた。

本研究は、東南アジアで森林減少・劣化又は森林増加及び木材炭素フラックスによる削減可能な量の研究を測定するモデル開発を行っている。これにより、森林減少・劣化を削減するための炭素削減量に応じて国際支援ができるようになることから、温暖化防止の国際交渉に貢献できると考えられる。東南アジア各国でもこれらのモデルを活用で、森林減少・劣化の削減等による炭素排出削減可能な量や吸収量の測定が可能なことを期待する。

以上の観点から、本論文は博士学位に値するものと認める。