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| 学位の種類 | 博士（応用情報科学） |
| 学位記番号 | 博情第３９号 |
| 学位授与年月日 | 平成２８年　９月２８日 |
| 学位授与の要件 | 学位規則第４条第１項該当（課程博士） |
| 論文題目 | Estimation of Carbon Emission Reductions and Costs for Reducing Local Dependency on Fuelwood Consumption in Cambodia<br>（カンボジアでのローカル薪利用削減による炭素排出削減可能な量及び削減コストの研究） |
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## 学位論文の要旨

Tropical deforestation was responsible for the release of 1 PgC yr-1 or about 6-17% of global carbon emissions. Deforestation is caused by many drivers and fuelwood extraction is an important driver of tropical deforestation and forest degradation in developing countries. This is because approximately 2.7 billion people or 40% of the global population rely on wood biomass to meet their residential needs of energy predominantly for daily cooking. Excessive consumption of fuelwood through the common use of three-stone cooking stove by forest-dependent community and burning of wood for protecting animal from insects have contributed to tropical deforestation and related carbon emissions in developing countries. Introducing more efficient cookstoves and the use of mosquito nets for insects' protection can reduce excessive consumption of fuelwood while improving local livelihood of forest-dependent community and reducing deforestation and related carbon emissions. Until recently, there is no study on potential carbon emissions and reductions from substitution of common practices with the use of improved cooking stoves and mosquito nets. Assessing carbon emissions and reductions through this substitution also contributes to the development of carbon accounting system necessary for developing countries to benefit from the carbon-based financial incentives REDD+ scheme of the United Nations Framework Convention on Climate Change.

Using a community located in Phnom Tbeng forest area in Cambodia as a case study, this study assessed fuelwood dependency quantitatively via random surveys of 105 households and to project potential carbon emission reductions realized by the substitution of three-stone stoves with improved cooking stoves and the use of mosquito nets instead of wood burning to protect animals. During the fieldwork, heads of households were targeted because of their main roles in daily family management. To perform cost effective analysis, three discounted rates were used to assess project development and implementation costs in terms of carbon prices for the substitution three-stone stove with improved cookstoves and the use of mosquito nets. Field surveys suggested that approximately 98% of the households collected firewood from nearby forests and used it as fuelwood for cooking, with the remaining 2% using both charcoal and fuelwood for this purpose. All respondents used the three-stone cooking stove for cooking. On average, fuelwood consumption was 2.0 ± 0.1 Mg household-1 yr-1 (± refers to Confidence Interval of 90%) for daily cooking, corresponding to 3.8 ± 0.2 MgCO2 of emissions. Burning wood for protecting cattle from insect consumed 4.3 ± 0.2 Mg household-1 yr-1 or 7.9 ± 0.3 MgCO2 of emissions.

Using results from the field surveys, population growth was projected for a period of 10 years between 2015 and 2024. Modeling suggests that households in the study site increased from 13,261 families in 2015 to 23,379 in 2024 based on the annual population growth rate of 6.3% in 2010. As population grows, more fuelwood consumption also increases and so do the carbon emissions. Carbon emissions from cooking and boiling water increase from 49,872 MgCO2 to 87,923 MgCO2, whereas emissions from burning fuelwood for protection against insects increase from 94,003 to 165,724 MgCO2. In total, carbon emissions from cooking, boiling, and burning fuelwood for protection against insects were estimated at 673,082 MgCO2 and 1,268,676 MgCO2, respectively for the 10-year modeling period. Total carbon emissions under the baseline scenario or in the absence of project activities were estimated at 1,941,759 MgCO2 over a 10-year period. To reduce these emissions, two project scenarios were compared. Under project scenario 1, Three Stone Stove has switched to Traditional Lao Stove with 43.11% of fuelwood saved. Second, project scenario 2 affords 64% of fuelwood saving by switching from Three Stone Stove to New Lao Stove. Under both scenarios, introduction of mosquito nets to replace

burning fuelwood for protection against insects has been implemented. Carbon emissions were estimated at 847,475 MgCO2 and 706,801 MgCO2 respectively under project scenario 1 and scenario 2, respectively for the 10-year modeling period. Therefore, by using improved cookstoves and mosquito nets to protect cattle, carbon emissions can be reduced up to 1.1 TgCO2 for the whole study site, corresponding to the avoidance of 6,187-6,983 ha of tropical forests from being cleared.

Substitution of conventional cookstoves with improved cookstoves and the use of mosquito nets instead of fuelwood burning could result in using less fuelwood for the same amount of energy needed and thereby result in reduction of carbon emissions and deforestation. To realize this substitution, approximately US$ 15-25 MgCO2-1 is needed depending on discount rates and amounts of emission reduction. These carbon prices are greater than carbon price traded in 2014, when average carbon price was just US$ 4.9 MgCO2-1, suggesting that carbon-based financial incentives alone is not attractive unless carbon price is set at the minimum level or financial support is provided to fill the gap. Carbon price is affected by the international agreement on climate change mitigation targets because it is driven by demand and supply. Carbon price is likely to increase after the 22nd Conference of the Parties to the UNFCCC, which is scheduled in 2016 when world leaders will agree to decide on emission reduction targets. In addition to reducing carbon emissions, substitution of cookstoves and mosquito nets will have direct impacts on the livelihoods of forest-dependent communities and on forest protection. Therefore, financial incentives under voluntary and mandatory schemes are needed to materialize this substitution.

Models developed in this study could be useful tools for carbon accounting through the use of improved cookstoves and mosquito nets. To improve accuracy of the models, field surveys according to seasonal variation are needed because households conduct daily activities by seasons.

# 論文審査の結果の要旨

森林減少・劣化による多くの炭素排出量は地球炭素排出量の 20%と示している。森林減少・劣化を削減することで、地球温暖化防止に貢献ができ、持続可能な開発もできると、期待されている。地球温暖化削減の REDD＋は、熱帯林の減少と劣化対策により気候変動を抑制するための国際的メカニズムであり、森林減少・劣化の要因を削減する。発展途上国において、薪利用は森林減少・劣化の要因の１つの重要な課題であり、この要因の削減について、注目されている。

本論は、カンボジアにある共有林を事例として、この森林減少・劣化の原因を削減する対策について着目し、薪利用を削減することによる、炭素排出削減可能な量とコスト及び対策方針を述べる。

第 1 章では、熱帯林における森林減少・劣化削減による炭素排出量と地球温暖化の原因について、国際交渉の解析について説明、国際支援を得るために、森林減少・劣化削減による削減可能な炭素排出量及び削減コストの研究必要性を見出した。

第 2 章では、文献解析で、森林減少・劣化及び炭素排出量、森林減少・劣化要因（特に燃料ための薪利用)、REDD+及び薪利用及びカンボジアにおける薪利用について、説明した。

第 3 章では、研究方法であり、カンボジアにおける森林現状から事例研究の現地特徴の森林資源現状、人口増加率や社会経済等を述べ、地元の薪利用についてのアンケート方法を説明した。また、アンケート調査のデータを基に、日常生活の燃料の算出方法を説明し、炭素削減量の測定するため、３つの調理用コンロ（石のコンロ、ラオスコロン１、ラオスコロン２）の使用による、それぞれの炭素排出量の測定方法を説明した。さらに、石のコンロ、ラオスコロン１、ラオスコロン２を導入することによる、炭素削減コスト方法も説明した。炭素排出量及び炭素排出削減コストの測定期間は 10 年間である。

第 4 章では、研究成果であり、アンケート調査解析による、90-100％の住民は日用生活の燃料として、薪を利用していると分かり、平均薪利用年間量は 6.35 トン／家族と判明。急速な人口増加があることで、急速な薪利用も増加する子による、炭素排出量も増加し、年間炭素排出量は 194,176 トン CO2 と測定した。３つの調理用コンロを使うことによる、炭素削減可能な量は年間 90,000-100,000 トン CO2 と分かった。炭素排出量を削減するためのラオスコロン１とラオスコロン２の導入することと、森林資源を守るために、US$15.25-25.05／トン CO2 のコストがかかると予測した。しかし、2015 年 REDD+プロジェクトからの炭素価格は US$4.90 しかないため、カンボジア政府又は国際機関からの支援が必要となると判明した。

第５章では、薪利用と共に炭素排出削減の実行可能になるため、ラオスコロンの導入及び森林保全しなければならない。コストを削減するため、政府からの支援が必要であり、炭素価格を 2011 年代の 30 ドルに戻るために、全世界の炭素排出削減目標を決めなければならないと考えられる。

第６章では、論文のまとめであり、論文背景、調査方法、研究結果と結論を述べた。森林からの薪を有効的な利用することより、森林減少・劣化と共に炭素排出削減ができると期待されている。

以上の観点から、本論文は博士（応用情報科学）の学位授与に値すると認める。