Malaria, Deforestation, and Plantation in Lao PDR: An Earth Observation Satellite Data Analysis

原　著

Malaria, Deforestation, and Plantation in Lao PDR: An Earth Observation Satellite Data Analysis

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ラオスのマラリア・森林減少・プランテーション：地球観測衛星データを用いた解析

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〔Abstract〕
Background: The habitat of malaria vector mosquitoes is strongly influenced by climate and vegetation. Our previous analysis suggested a positive correlation between malaria incidence and forest area in Lao PDR. However, in Phouvong District, Attapeu Province, a malaria-endemic region in Lao PDR, the number of malaria cases increased despite a decrease in forest area from 2000 to 2017. Therefore, this study aimed to identify the factors contributing to the rise in malaria cases using Earth Observation Satellite data. Methods: Focusing on Phouvong District in the southern region, where cases of malaria are particularly high, we conducted three key analyses: (1) examination of forest coverage data (MODIS MOD444B), (2) generation of deforestation maps from forest coverage images, and (3) identification of changes in forest coverage using maps and Landsat satellite images to assess land use. Results and Discussion: We identified areas of increased forest cover after 2009, all of which were determined to be planted forests divided into 0.5 km squares. Notably, a significant surge in afforestation occurred between 2010 and 2012 following demarcation, which coincided with an increase in malaria cases. Through field observations, we confirmed that the presumed planted forest areas included plantations of rubber, sugarcane, banana, and other crops, as well as housing complexes and factories. This finding suggests that these areas may represent another significant focus of malaria transmission. It underscores the importance of conducting a comprehensive survey of primary vectors and the living conditions of malaria patients.

〔Key words〕Lao PDR, Malaria, Deforestation, Plantation, Earth Observation Satellite Data

〔要　旨〕
背景：マラリア媒介蚊生息域は気候や植生に大きく影響を受ける。ラオスでは森林面積が増加するとマラリア罹患率が増加する傾向が示唆された。ところがラオスのマラリア流行地であるアタプー県プーボン郡では，2000年から2017年にかけて森林面積が減少しているにも関わらず，マラリア患者数が増加し

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ていた。方法：そこで本研究はこの17年間の地球観測衛星データ（植生）を用いて，マラリア患者数の増加に寄与する因子の推定を試みた。結果と結論：2009年以降，森林面積が増加したエリアが確認され，それらは全て0.5km四方に区画された人工林であった。特に2010年から2012年区画整理後の植林が顕著に増加し，その期間，同郡内のマラリア患者数も増加した。現地観察により人工林と推定された地域の一部は，ゴム，サトウキビ，バナナなどのプランテーションであり工場と宿舎も認められた。特にプランテーションにおいて，メインベクターやマラリア患者の生業等を詳細に調査する必要がある。

〔キーワーズ〕ラオス，マラリア，森林減少，プランテーション，地球観測衛星データ

Ⅰ. Introduction

More than 600,000 people still die of malaria every year in the world and most of them are children[1]. It is also estimated that an additional 13.4 million malaria cases occurring between 2019 and 2021 were attributed to disruptions caused by the COVID-19 pandemic. Even with the continuous efforts made to maintain services during the pandemic, malaria control faces a number of hurdles, including a prolonged humanitarian crisis, limited donor funding, and the potential impact of climate change on the spread of the disease.

The impact of climate change, including rising land surface temperature (LST), changing precipitation patterns, and extreme weather events, on malaria is becoming increasingly evident[2]. Malaria is transmitted to humans through the bites of infected female *Anopheles* mosquitoes, and variation in climate conditions (such as LST and precipitation) has a profound effect on the longevity of the vector mosquito and on the development of malaria parasites in the mosquito and, subsequently, on malaria transmission[3, 4]. Besides, climate change may cause some areas that were previously unexposed to malaria to be at risk, resulting in a 50% higher probability of malaria transmission by 2050[5].

A previous analysis showed that the distribution of malaria vector mosquitos in Lao PDR has been affected not only by increasing LST but also by increasing amounts of forested land suitable for mosquito ecology[6]. Forest ecosystems provide favorable conditions for the predominate vector mosquitoes, *Anopheles dirus*, and changes in forest cover can have pervasive and multifactorial effects on the ecology of the vectors and the pathogens they transmit.

Therefore, the present study was undertaken to estimate the environmental factors (deforestation, LST, and precipitation) that contribute to the increase in the number of malaria patients in Phovong district, Attapeu Province, one of the malaria endemic region in Lao PDR. The findings of the present study will provide evidence for the elimination of malaria in Lao PDR.

Ⅱ. Methods

Epidemiological data were collected from the Lao PDR Center of Malariology, Parasitology, and Entomology (CMPE), National Institute of Public Health (NIOPH), and Institut Pasteur du Laos (IPL). The available data on the distribution of malaria (e.g., area, population, number of malaria patients, malaria species, etc.) were collected and used to calculate the following indicators such as the annual parasite index per 1000 population (API), the positivity rate of collected slide samples (SPR), and the percentages of *Plasmodium falciparum* and *P. vivax*.

Earth Observation Satellite data including the MODIS Vegetation Continuous Fields products (MOD44B)[7] derived from Earth observation satellite data between 2007 to 2015 for Lao PDR as a whole, focusing on Phouvong District, which has a particularly high prevalence of malaria, were obtained from LP DAAC (https://lpdaac.usgs.gov) to analyze forest cover change. This product covers the entire globe, and each grid (250 m grid size) includes information on the percent of tree cover, non-tree vegetation, and bareness. Maps from Google Earth were also used.

First, the percentage of forest change and deforestation maps were created by time-series analysis of Earth Observation Satellite data, MOD44B data (2000-2017). Second, information on the number of malaria cases was obtained from the Lao PDR Ministry of Health, and the numbers of malaria cases in each area were estimated, and the indicators (API, SPR, and percentage of *P. falciparum* and *P. vivax*)

were calculated. Finally, utilizing the aforementioned maps, Landsat satellite imagery (1984～2019), and fieldwork data, areas where forest coverage has undergone changes in land use were identified and analyzed (such as for vegetation, the presence of factories, dwellings, etc.). All statistical analyses were carried out using SPSS version 24.0, and geographic analyses were performed using QGIS version 3.28.10.

Ⅲ. Results

1. Deforestation in Lao PDR

Deforestation in the entire Lao PDR was analyzed using satellite MODIS MOD444B data (Figures 1 and 2). The results showed that there were no apparent changes in forested areas in each province from 2007 to 2010, whereas deforestation was observed from 2010 to 2015 in all of the provinces (Figure 1). Overall, as much as 38.5% of the forested areas was deforested during these 5 years.

The percentage of deforestation was higher in northern Lao PDR (Figure 2) and, specifically, in the provinces along the Thai and Vietnamese borders. For example, in Boeko province located on the Thai border, the percentage of deforestation reached 79.4%.

2. Malaria in Lao PDR

Malaria was prevalent mainly in the southern regions (Figure 3), and the API was shown to be increased southward toward the border with Cambodia. In fact, there were some districts with APIs of higher than 50. For example in Phovong district near the border, the API was 63.7, the SPR was 13.8%, the percentage of *P. falciparu*m was 7.9%, and that of *P. vivax* was 42.1% in the year 2015.

3. Deforestation and malaria

In Phovong district, increased forest coverage was identified in some areas after 2009, which were shown to be the planted forests divided into 0.5 km squares on the map (Figure 4). In particular, from 2010 to 2012, the marked increase of afforestation in the district correlated with the number of malaria cases (650 cases in year 2010, 1587 cases in year 2011, and 2457 cases in

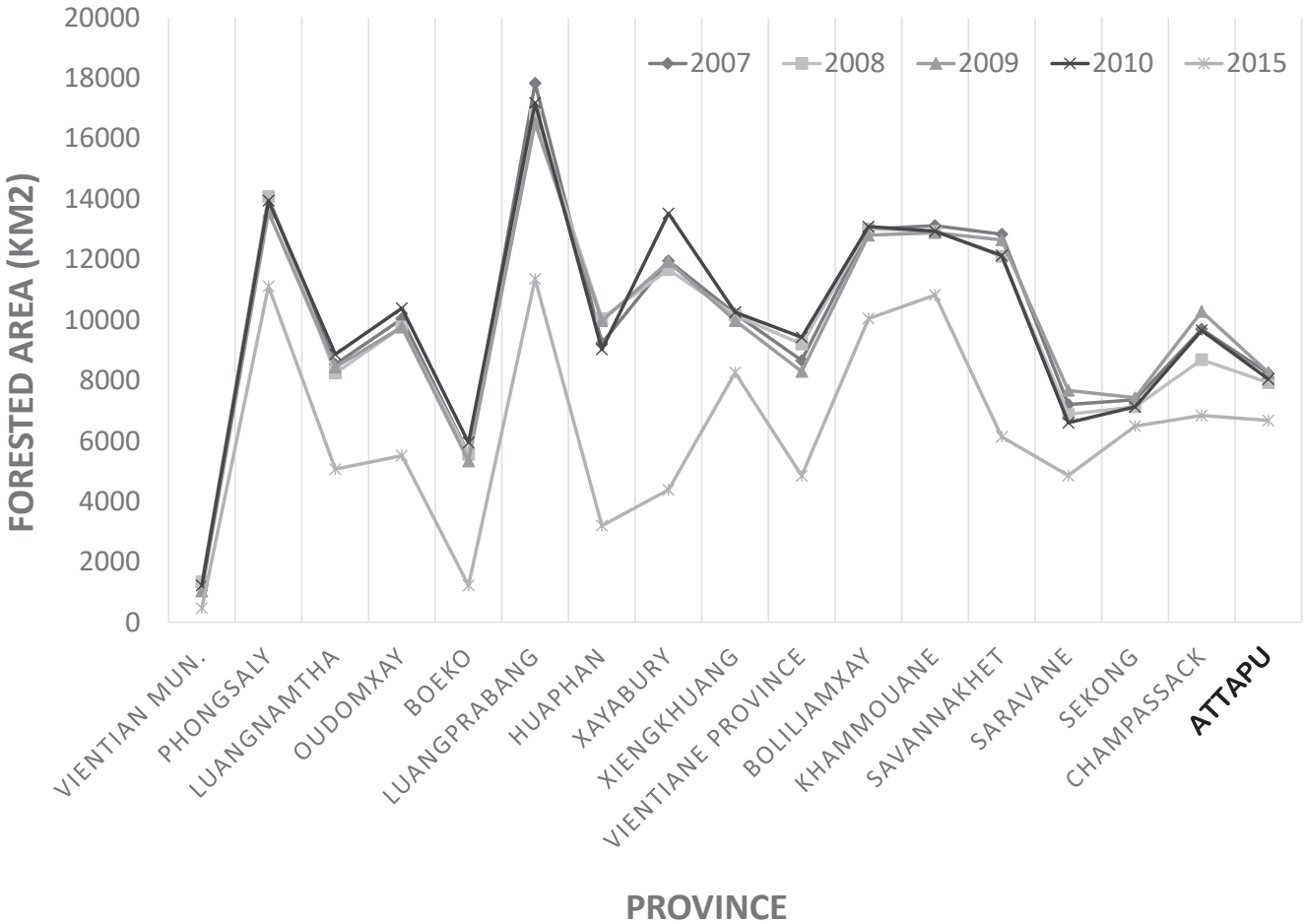

Figure 1. Deforestation in Lao PDR per province during 2007 to 2015

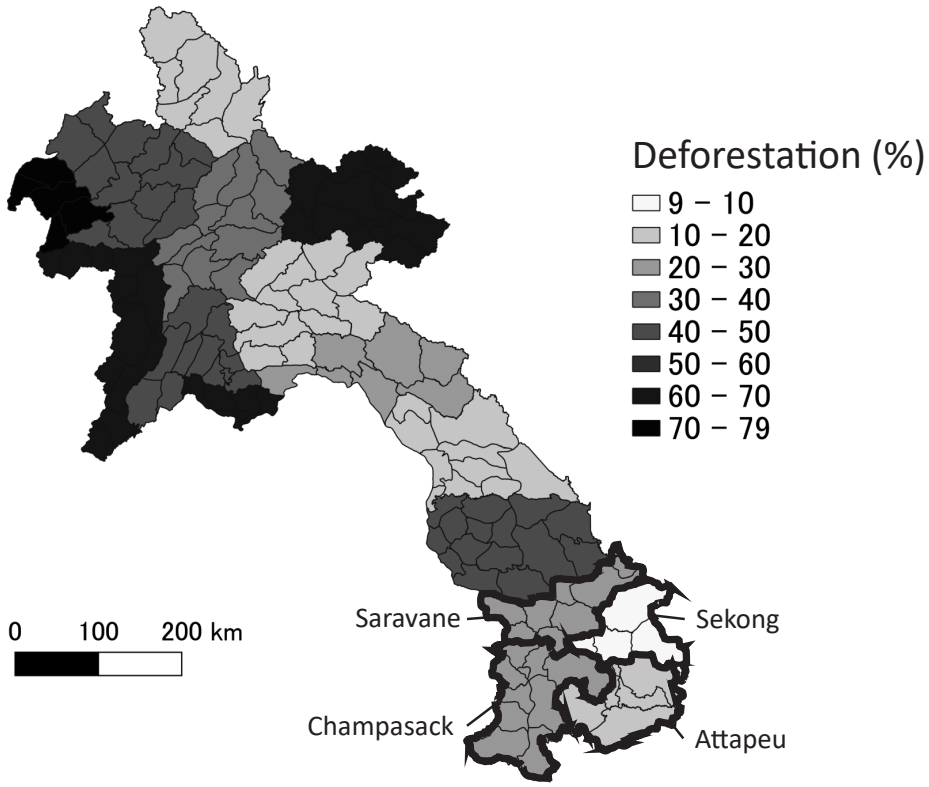

Figure 2. Percentage of deforestation (%) in Lao PDR from 2010 to 2015

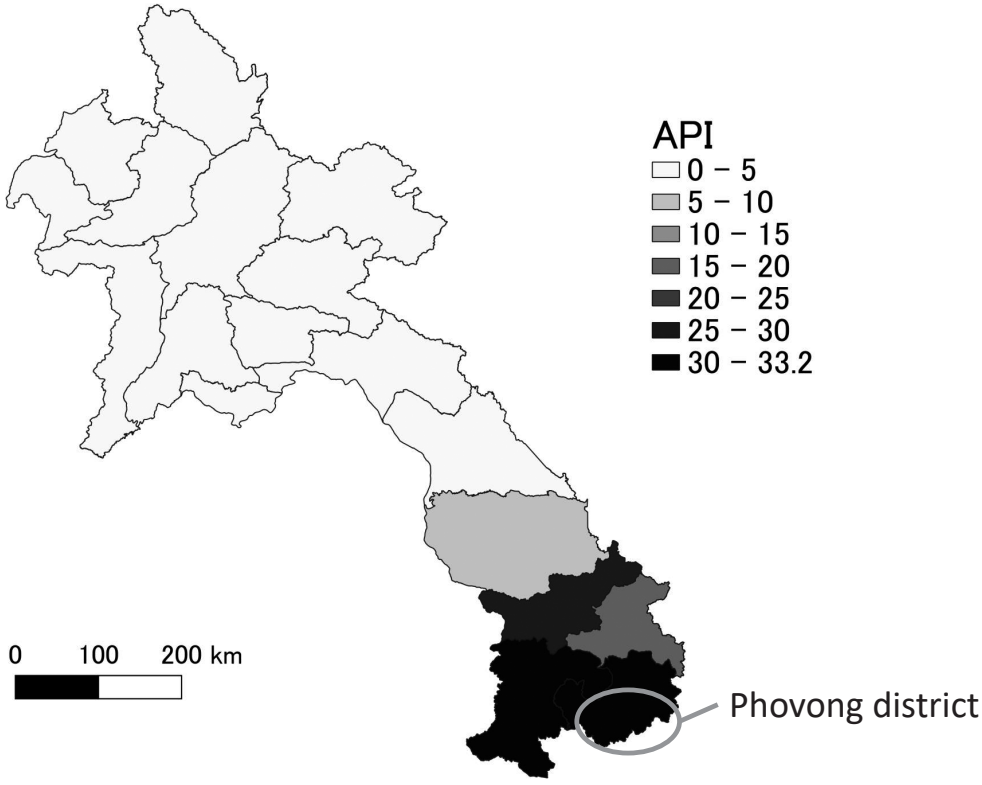

Figure 3. Annual parasite index (API) per province in Lao PDR in year 2015

year 2012).

In the planted forest, buildings were also observed on Google Maps (Figure 5). The areas that were presumed to be planted forest based on Earth Observation Satellite data were found by field observation to be plantations of rubber, sugarcane, banana, and other crops.

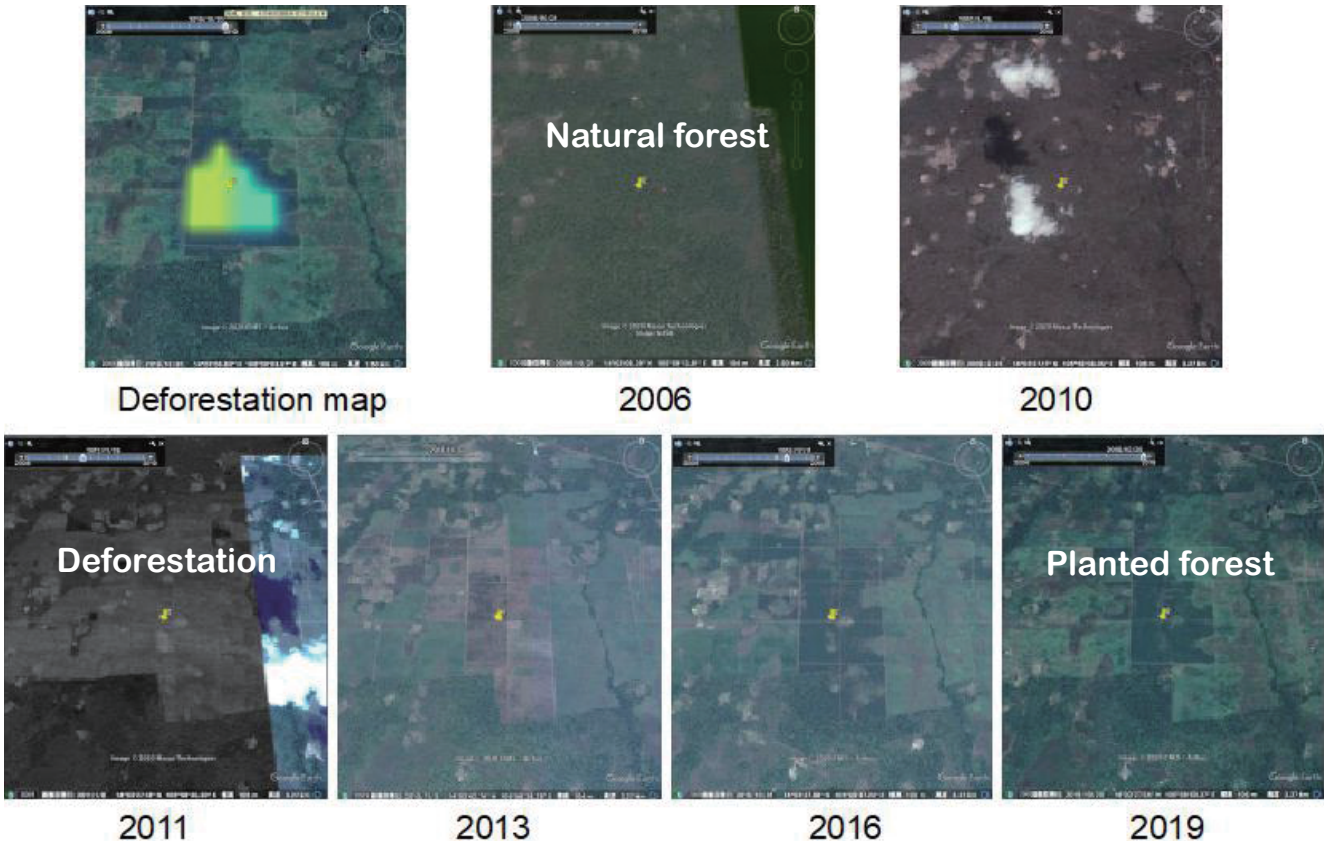

Figure 4. Transition from natural forest to planted forest
Deforestation map in an area in Phovong district derived from MOD44B, 2006, 2010, 2011, 2013, 2016, and 2019 imagery from Google Earth, respectively. The area was a natural forest in 2006, but then the forest was cleared in 2011, a road was built, and it became a planted forest in 2019.

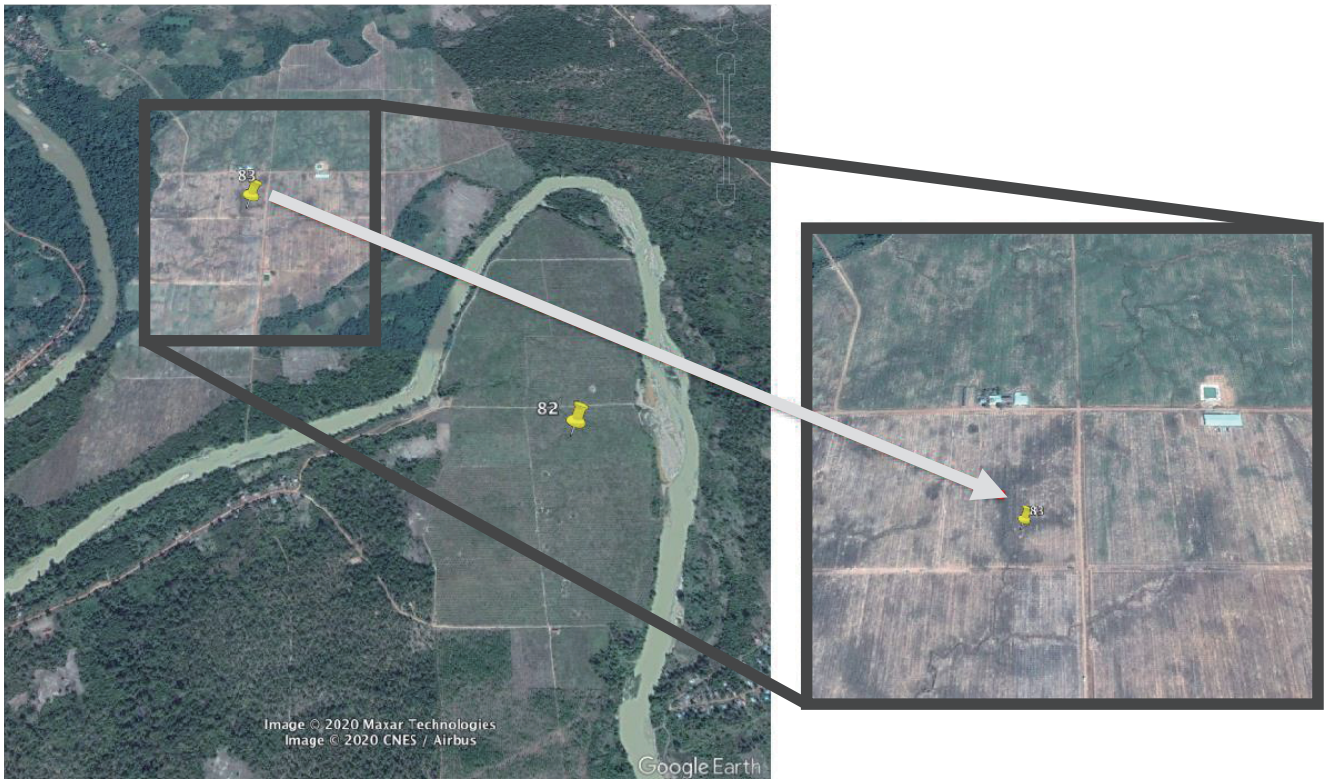

Figure 5. One of the planted forest in Phovong district (Google Earth)

Ⅳ. Discussion

Lao PDR is a landlocked country with much of its land area covered by mountains and a significant portion of the population residing in its forested areas. In comparison to neighboring countries, the region had relatively abundant forest resources and was once considered one of the countries with the richest biodiversity in Southeast Asia. However, as our study has revealed, rapid deforestation has emerged as a significant environmental concern[8,9] In fact, Lao PDR has been losing forest due to both legal and illegal logging. For example, in 2020, more than 2,600 cubic meters of illegally harvested wood and over 290 tons of illicit timber were seized[10].

While deforestation has affected many parts of Lao PDR, the prevalence of malaria is particularly high in the southern regions. In Phovong district near the border with Cambodia in the southern region, afforestation trends following deforestation in the district were presumed to have increased the API to as high as 63.7. Because the predominating malaria vector in Lao PDR is *A. dirus*[11], which likes a forested environment, human communities living in the forests could be the focus of transmission[12-14].

The present study aimed to analyze the impact of deforestation on the distribution of malaria in Lao PDR using malaria epidemiological data and Earth Observation Satellite data. However, issues with afforestation, particularly from 2010 to 2012, with a marked increase in plantation after demarcation into 0.5-km squares after deforestation, were noted.

While most studies examining the relationship between climate change and the distribution of malaria primarily focus on ground surface temperature and precipitation[12-15], there is an imperative need to conduct a detailed survey of vegetation, particularly in areas where primary vectors are found (plantations, etc.), and of the livelihoods of malaria patients.

Ⅴ. Conclusion

Rapid deforestation was observed throughout Lao PDR. Malaria was prevalent mainly in southern Laos, and deforestation was also observed in this area. The present analysis also confirmed that the apparent increase in forested areas in this region primarily consists of planted forests such as plantations that are divided into 0.5 km squares. This finding suggests that these areas may represent another significant focus of malaria transmission. To eliminate malaria in the country, there is a pressing need for a comprehensive survey focused on the primary vectors and the living conditions of malaria patients within these planted forests.

Ⅵ. Disclosure

There are no conflicts of interest to disclose.

Ethics approval

Not applicable because the preset study uses publicly available epidemiological and Earth Observation satellite data, and does not involve the direct participation of research subjects.

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