Shifting Cultivation at a Crossroad

Drivers and Outcomes of Recent Land-Use Changes in Lao PDR

Project team

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Introduction and Workflow

The Lao PDR (Laos) presents a unique opportunity to examine recent land cover and land use changes (LCLUC), their drivers, and outcomes both for ecosystem service provision as well as for poverty and inequality, which are typical for the Southeast Asia region. Laos has a high proportional national forest cover and a large rural population. Agriculture plays a central role in the national economy and a large majority of the rural population are subsistence farmers whose income and food supply depend on shifting agriculture. The national government's dual objectives to reduce deforestation and eliminate poverty led to various interventions, investments, and regulations aimed to replace shifting cultivation with permanent agriculture and industrial plantations, resettle villages in remote areas of the country, and implement sustainable development projects.

Approaches prototyped by our research team in Southeast Asia allowed us to **map and estimate the area of LCLUC over multiple decades** using the Landsat data archive. Laos has an extensive collection of national socio-economic data, including **Lao Expenditure and Consumption Survey (LECS)** data for 2002/3, 2007/8, and 2012/13, and **Population and Housing Census (PHC)** data for 2005 and 2015. These datasets, available through project collaborators, the Center for Development and Environment of the University of Bern, allowed us to **quantify relationships between LCLUC and changes to inequality and human well-being** throughout the past three decades at the national and regional levels. Due to the travel limitations, the originally planned in-field data collection was not implemented. Instead, our research focused on the analysis of the nationally representative LECS and PHC data and remote sensing-based metrics to quantify the socioeconomic effects of the land use transitions.

Goal and Objectives

The **overarching goal** of the project is to quantify trends in the evolution of shifting cultivation systems, to associate specific transition pathways with corresponding trajectories of inequality and human well-being, and to understand the socio-environmental outcomes of land sparing policies.

This is done through the following **project objectives**:

1. Mapping and quantifying change in shifting cultivation landscapes and tree plantation establishment annually, from 1988 to 2019.
2. Evaluation of linkages between changes in LCLUC, specifically, rubber plantations establishment and forest extent change, with multidimensional inequality and human well-being.

Research Hypothesis

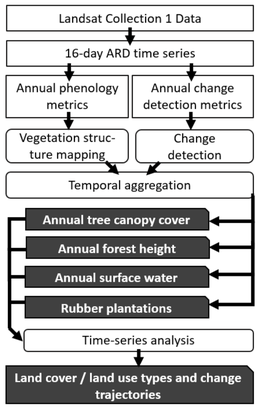
[Hypothesis 1] Each distinct shifting cultivation transition landscape is associated with different inequality and well-being trajectories and outcomes.

[Hypothesis 2] Household income, land holdings, ecosystem service access, and overall well-being become more unequally distributed as a result of changes in shifting cultivation systems. The greatest increase in inequality will be observed in villages directly affected by industrial plantation expansion or closest to the urban centers.

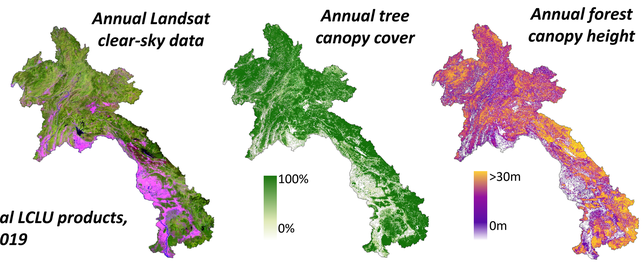
[Hypothesis 3] Economic well-being, including income, will increase in the short term after shifting cultivation transitions to more intensive land uses. Levels of multidimensional well-being are generally higher under shifting cultivation than other land uses, and short-term income gains after transitions will be offset by decreases in other aspects of well-being over medium- and long-term timeframes.

[Hypothesis 4] The ecosystem function of forests, specifically carbon sequestration, increases in areas where shifting cultivation is replaced by regrowing natural forests, but decreases where shifting cultivation mosaics are replaced by industrial rubber plantations.

Land Cover and Land Use Change Analysis



Landsat image archive is the only data source suitable for the multi-decadal LCLUC assessment. To facilitate the three-decade analysis of land cover change, we have implemented an automated system for Landsat data processing (Potapov et al., 2020). Using the Landsat ARD surface reflectance time-series data, we have **developed and applied annual models to map surface water extent, tree canopy cover, forest height, forest disturbance, and rubber plantation extent** (at 4-year intervals). The products were integrated to provide comprehensive national LCLUC information for the last three decades (1988-2019). The LCLUC metrics were aggregated at the village level to correspond with the socio-economic census data. The ARD data and tools and national LCLUC products were shared with the National University of Laos, Laos Department of Forestry, SERVIR_Mekong, and nature conservation consulting businesses (Aruna Technology Co. and Kokusai Kogyo Co.) to support data application by national researchers.

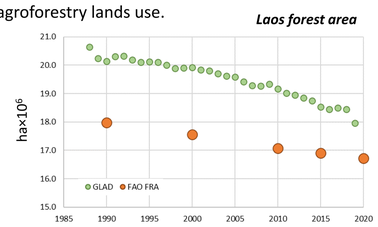


National LCLU products, 1988-2019

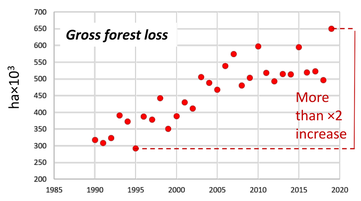
Potapov, P., Hansen, M.C., Kommareddy, I., Kommareddy, A., Turubanova, S., Pickens, A., Adusei, B., Tyukavina A., and Ying, Q., 2020. Landsat analysis ready data for global land cover and land cover change mapping. Remote Sens. 2020, 12, 426; doi:10.3390/rs12030426

We defined forest as land with tree canopy cover of ≥10% and tree height of ≥5m. Our map-based results shows that the **forest area decreased by 11% from 1990 to 2019**. The official data (FAO FRA 2020) shows similar forest loss trend but lower area due to exclusion of the agroforestry lands use.

Laos forest area

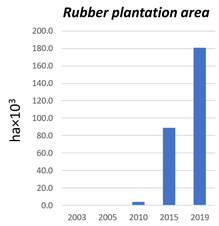


The observed forest loss trend is aligned with the **increasing area of annual forest disturbance events**, that include permanent deforestation, shifting cultivation, and agroforestry management.



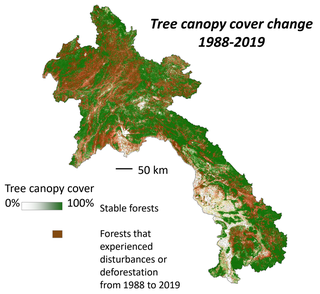
Hydropower projects play important role in total deforestation and are responsible for the loss of 0.5% of all primary forest since 1988.

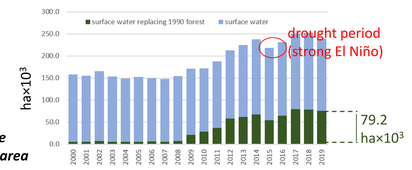
Rubber plantation area



Our results confirmed **dramatic expansion of rubber plantations** over natural forests and shifting cultivation areas since 2010.

Tree canopy cover change 1988-2019

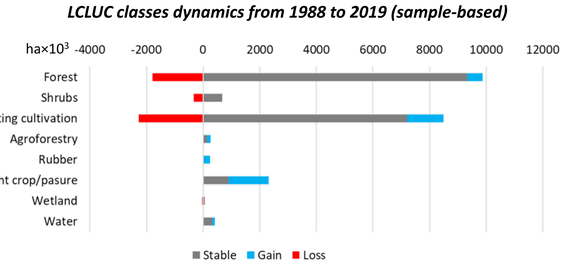




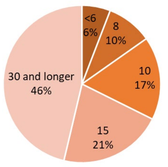
Surface water area

Landsat-based products do not have sufficient spatial resolution to extract detailed information about land management. Moreover, as our LCLUC trajectories map derived from time-series of vegetation structure models, they may lead to area estimation bias due to model errors and source data limitations. We implemented a **probability sampling method for measuring map accuracy and estimating the unbiased area of LCLUC classes** following recommended good practices for remotely sensed data product validation. We used a stratified random sampling design using Landsat pixels as sampling units. Stratification was based on LCLUC trajectories that target our classes of interest: shifting cultivation change, rubber plantation expansion, and forest loss drivers.

LCLUC classes dynamics from 1988 to 2019 (sample-based)



Sample analysis also allowed us to quantify **rotation intervals within shifting cultivation landscapes**. We found that more than 1/3 of the shifting cultivation area was characterized by long rotation intervals (longer than 10 years), confirming the need to use multidecadal data for analysis.



Rotation interval, years. The total area represent stable shifting cultivation landscapes (7.2 million ha)

LCLUC trajectories within year 1988 primary forests

	Area, ha×10³	% Total
Undisturbed	8,831.2	79.5
Disturbed (logging, fires) and degraded	572.8	5.2
Converted to agroforestry, permanent agriculture, settlements, infrastructure	298.7	2.7
Converted to rubber	75.5	0.7
Shifting cultivation expansion	1,284.3	11.6
Flooded	51.2	0.5
Total	11,113.7	

Rubber plantation area

ha×10³	2019
Rubber plantations area (map)	180.7
Rubber plantations area (samples)	246.6
95% confidence interval	76.6
2018 planted area (Smith et al., 2020)	258.4

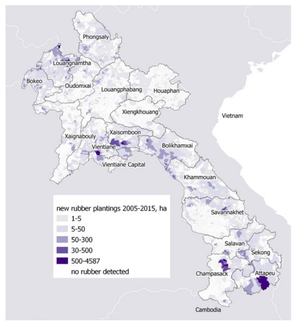
Map-based and sample-based forest area

ha×10⁶	1988	2019
Forest area (map)	20.6	18.0
Forest area (samples)	20.2	17.5
95% confidence interval	1.5	1.6

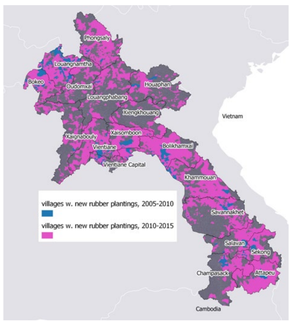
Rubber plantations establishment and their implications for voluntary sustainability programs in Lao PDR

We investigated **changes in rural economic inequality and polarization in the context of rapid growth in rubber production** and examined the implications of these trends for voluntary sustainability projects (SDGs). To analyze trajectories of uneven development and their relationship to regional rubber production we used the village-based data on rubber plantation extent and change. For our income proxy, we used annual household consumption per capita from the LECS survey. We assess inequality primarily through the calculation and decomposition of the Gini coefficient, Thiel L, and T indices. To measure economic polarization, we employ the Duclos Estaban Ray index. We calculated these inequality and polarization metrics for the three main geographic regions of the county (North, Central, and South) and by rubber production status.

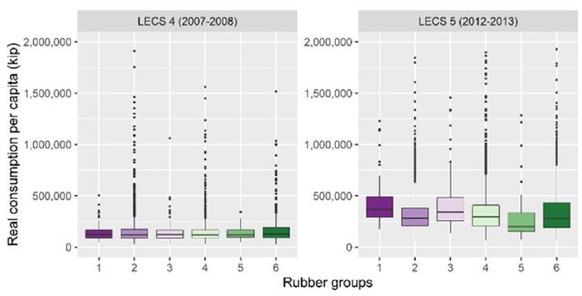
Our results indicate that **rubber-producing areas experience greater inequality and polarization compared to their non-producing regional counterparts**. We find that inequality and polarization effects varied regionally by the type of production system used to grow rubber (concessions, smallholder, and contract farming). The inequality- and polarization-enhancing effects of rubber production were greatest in the South, which is dominated by large-scale concessions. The Central region also exhibits higher increases in inequality in rubber production areas as compared to nonrubber areas. In the North, where smallholder production is dominant, inequality and polarization levels decrease, but rubber-producing areas exhibit a smaller reduction than nonrubber areas. We argue that these differences are important to account for in the design of rubber sustainability interventions and that these programs must consider and engage the mechanisms by which inequality and polarization manifest in rubber production. This includes factors like tenure security and dispossession from land and forest resources; insufficient worker protections; potential livelihood vulnerability driven by price volatility; barriers for smallholders; and gender and ethnic inequality.



Rubber plantation establishment per village area.



Village groups by the rubber plantation expansion.



Annual real consumption per capita by rubber production group. Geographical groups 1-2 – North, 3-4 – Central, 5-6 – South. Rubber plantation groups: 1,3,5 – with plantations, 2,4,6 – without plantations.

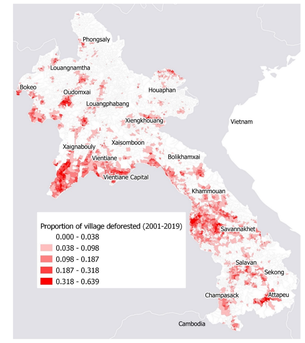
Traldi R., Silva J.A., Potapov P., Tyukavina A., Epprecht M., Gore M., Phompila C. Cultivating Inequality? Regional rubber dynamics and implications for voluntary sustainability programs in Lao PDR. *World Development, under review.*

The poverty and forest cover impacts of voluntary sustainable development projects in Lao PDR from 2005 to 2015

The study examines a set of voluntary sustainable development projects (SDPs) which aimed to reduce poverty, maintain forest cover, and/or protect wildlife habitats. These projects are focused on food security and livelihoods diversification (irrigation, livestock, nutrition, and livelihoods development), sustainable forest management, and sustainable resource management (primarily focused on habitat conservation). The main research question of the research was: **To what extent did voluntary SDPs in Laos affect poverty and forest cover between 2005 and 2015?** We hypothesize that SDPs focused on food security and livelihood diversification will have poverty-reducing effects and the sustainable resource management SDPs will have positive effects on forest cover. By evaluating poverty and forest cover simultaneously, we also assess the potential co-benefits of SDPs for both outcomes.

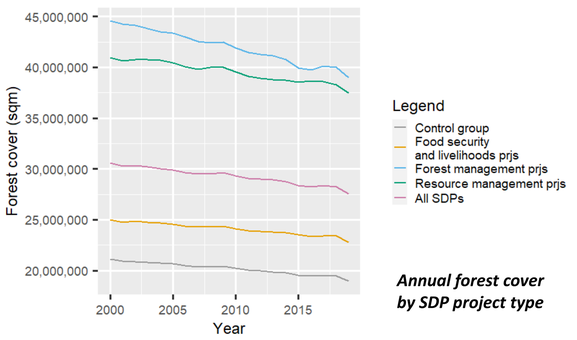
We evaluate 72 SDPs implemented between 2007 and 2013 in 1,452 villages in Laos through an inverse probability-of-treatment weighted regression (IPWR). The outcome variables include 2015 poverty headcount in percent and 2015 percent forest cover. Poverty data was derived from national Laos 2015 Population and Housing Census. The analysis included drawing the directed acyclic graphs from subject matter theory, articulating the project typology, outcome variable calculation, covariate selection and geospatial processing, doubly robust IPWR estimation of the average treatment effect, and sensitivity analyses to probe the results' robustness to potentially unobserved confounding.

We found that **SDPs overall had a positive impact,** with effect heterogeneity among different project types. **Food security and livelihoods projects exhibited significant positive impacts** on both poverty and forest cover in 2015. **Sustainable resource management projects showed the highest positive effects for forest cover maintenance**, but no significant effects on poverty. **Sustainable forest management projects showed no significant effects on either outcome**. We explore potential drivers of these results, arguing that the co-benefits of food security and livelihood projects present a promising topic for future research. Additionally, the mixed outcomes of resource and forest management projects necessitate further study, due to the importance of these interventions for land-based climate change emissions reduction and sustainable development.



2001-2019 deforestation proportion of the village area

Trends in mean forest cover per village, 2000-2019



Annual forest cover by SDP project type

Traldi R., Steiner P.M., Sauer J., Potapov P., The poverty and forest cover impacts of voluntary sustainable development projects in Lao PDR from 2005 to 2015. *Prepared for submission to PNAS.*

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NASA Land Cover Land Use Change program
Grant # 80NSSC20K0363

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