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REGULAR RESEARCH ARTICLE

Understanding the Safeguarding Role of Forest Resources and Its Determinants During the COVID-19 Pandemic: Insights from Vietnam, Laos, and Cambodia

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ABSTRACT

Sustainable forest management can play a vital role in building resilient economies and communities that can withstand pandemics, climate change, and other global challenges. Through a comprehensive analysis of local communities surrounding protected areas, we examine the extent of forest reliance for livelihoods and identify key drivers behind changes in forest-resource use during the pre-pandemic in 2019 and post-pandemic in 2022. The study's findings reveal a noteworthy increase in the proportion of land utilized for livelihood activities, especially for production forests, in study sites between 2019 and 2022. Local communities still heavily rely on forest resources for their livelihoods, with a significant increase in household income derived from forest-based activities between 2019 and 2022, approximately 112.1%, 28.7%, and 1.68% for Vietnam, Cambodia, and Laos, respectively. Additionally, the study highlights an upsurge in forest dependence during the pandemic period, emphasizing the importance of forests in safeguarding the economies of forest-dependent communities. Findings also shed light on the determinants of forest dependence changes amid the pandemic, including income from forests, poverty status, minority group status, and receipt of COVID-19 relief. These results provide valuable insights into the relationship between forest resources and rural livelihoods for promoting sustainable forest management and safeguarding the well-being of local communities in the face of future challenges.

KEYWORDS

Forest resources; Livelihood dependence; Safeguarding role; COVID-19 pandemic; Rural households.

1. INTRODUCTION

Southeast Asia (SEA) is home to approximately 15% of the world's tropical forests, providing sustenance to more than 140 million individuals who heavily rely on forest resources for their livelihoods (Estoque et al., 2019; Poffenberger, 2006; RECOFTC, 2021). These regions are dependent on forest-based ecological services and products, including wood fuel, food, and medicinal resources, which are crucial for the well-being of rural communities residing in and around protected areas (Neumann & Hirsch, 2000; Angelsen et al., 2014; Iswanto et al., 2022). However, SEA faces significant deforestation, making it one of the world's leading deforestation hotspots, primarily due to human activities such as the unsustainable exploitation of natural resources and forest conversion (Estoque et al., 2019).

Forest dependence encompasses the intricate relationship between human populations and forest resources, exemplifying the reliance on forests for livelihoods and resilience amid various disruptions, including pandemics and environmental shocks (Hussain et al., 2019; Frey et al., 2022; Ntiyakunze & Stage, 2022; Phan et al., 2022a; Panpakdee & Palinthorn, 2021). These forest resources and their associated ecosystem services are fundamental for meeting human needs, supporting environmental functions, and crucially, safeguarding human well-being in the face of emerging threats such as climate change and disease outbreaks (Lobry de Bruyn et al.,

2022; Tan et al., 2023). Amid the COVID-19 pandemic, local communities have confronted challenges in sustaining their livelihoods, prompting a turn towards forest areas for support. The situation is especially pronounced in countries such as Laos, Cambodia, and Vietnam, where social safety networks are limited, and vulnerable populations are prevalent (ASEAN Briefing, 2022, and see Appendix 1 for the situation of pandemic outbreaks in 2020-2022). Consequently, the implementation of lockdowns and border closures has impeded economic activities and disrupted supply chains, resulting in economic contractions and a marked increase in poverty rates.

In the face of such challenges, forests have assumed even greater importance in supporting human welfare in developing countries through sustainable farming practices, agroforestry, and other income-generating activities (FAO, 2008; Soe & Yeo-Chang, 2019; Bista et al., 2022). The COVID-19 pandemic has further exacerbated this problem, particularly in remote forest-dependent communities that face limited access to public services and information, leading to socio-economic challenges (see Appendix 3 for problem trees of forest dependence in the three study sites). Despite the extensive documentation of the pandemic's impacts on public health, the economy, and the environment (Ali et al., 2020; Amador-Jiménez et al., 2020; Lindsey et al., 2020; Laudari et al., 2021; Njana et al., 2021; Maraseni et al., 2022; My et al., 2023), studies focusing on the safeguarding role of forests in the study area are still limited (Sapkota, et al., 2022). Moreover, there is limited research on the livelihood impacts of the pandemic on forest-resource use, particularly in developing countries within Southeast Asia. The imposition of long-term lockdowns and the scaling back of forest monitoring systems in the region have given rise to concerning trends, including deforestation, forest degradation, and illegal activities like poaching, mining, and land grabbing (FAO, 2020; Troëng et al., 2020; Phan et al., 2022b). Consequently, there is an urgent need for further investigation and concerted efforts to comprehend the utilization of forest resources during the pandemic. Such endeavors are critical in safeguarding human well-being against incoming emerging threats, fostering sustainable forest management, and supporting post-pandemic recovery initiatives.

This study offers a comprehensive analysis on forest resources used by local communities residing in protected areas of Vietnam, Laos, and Cambodia during the COVID-19 pandemic. It investigates the extent of forest reliance for livelihoods and identifies key drivers behind changes in forest-resource use during this unprecedented period. By examining the experiences in these three countries, the study enhances our understanding of the impact of unforeseen events like the pandemic on rural communities and the safeguarding role of forest-related resources for local people's livelihoods. The findings have significant implications for understanding the safeguarding role of forests, improving community resilience, and advancing sustainable forest management in the region. The remainder of this paper is organized as follows. The next section describes materials and methods used in the study. Section three presents the empirical results and discussion. Finally, section four provides the concluding remarks.

2. METHODS

2.1 Selection of study sites

To identify appropriate study sites, we conducted literature review and Key Informant Interviews (KIIs) with five experts from the Ministry of Agriculture in each of the three countries. Drawing on insights from a literature review and expert consultations, we established selection criteria for the study sites. These included identifying forest ecosystems that were representative of each country, as well as communities with

diverse livelihoods and levels of dependence on forests in the context of the COVID-19 pandemic. We also sought out areas that were targeted by local and national policies for forest governance. Based on these criteria, we selected one protected area in each country that best exemplified the desired characteristics of forest ecosystems, forest-dependent livelihoods, and forest dependence (Figure 1).

Figure 1. Locations of selected study sites of the three countries (A summary of the main characteristics of the selected sites is provided in Appendix 2).

Vietnam's forests are primarily situated in coastal wetlands and mountainous regions, with Phong Nha-Ke Bang in Quang Binh Province being the largest protected karst landscape in Southeast Asia, covering 123,326 hectares. The park boasts a diverse range of habitats, including terrestrial and aquatic environments, primary and secondary forests, natural regeneration sites, dense tropical forests, and remarkable caves with scientific significance (Van-Mai, 2020). The park's buffer zone is home to 64,000 individuals residing in 13 communes, primarily comprising ethnic minority communities who rely heavily on forest-related resources for their livelihoods. Nam Kading Protected Area (NKPA) in central Laos is a crucial forest ecosystem that covers 92% of Bolikhamxay Province (169,000 hectares) and contains a significant Mekong River tributary. The NKPA provides livelihoods for approximately 7,265 households residing in 36 villages, consisting of 44,076 residents in the core area and 24,507 individuals in the buffer zone's 18 villages and 4,020 households. The predominant ethnic groups in the region are Lower Lao, Khmu, Hmong, Meuy, Yor, and Tai. Virachey National Park (VNP) in Cambodia (338,057 hectares with total population residing in the buffer zone to be around 15,000 individuals) faces numerous threats, including poaching and illegal logging, which have depleted the forest's resources. Forest conversion and land use have also contributed to the loss of timber and threatened the biodiversity of the region, thereby putting the forest-dependent communities at risk (Singh et al., 2022). Sustainable resource extraction practices are being implemented, and urgent measures are required to manage the forests and biodiversity to mitigate the losses.

2.2 Data collection

Two rounds of Focus Group Discussions (FGDs) were conducted at each of the selected study sites, bringing together local authorities, forest managers, and community members residing in communes surrounding the protected areas. Each FGD comprised of 8-11 participants and aimed to provide an in-depth understanding of forest resources, forest utilization patterns, the pandemic's impact, challenges faced by forest-dependent communities, and identifying potential communes for subsequent household surveys. Subsequent to the FGDs, a comprehensive semi-structured household survey was conducted to delve deeper into forest resource use and the extent of dependence on forests. The face-to-face survey encompassed 241 households located within three designated protected areas, with representation from 150 households in Vietnam, 60 in Cambodia, and 60 in Laos. Employing a stratified random sampling approach, the communes inhabited by respondents within and around the cores of the selected protected areas served as the strata. Respondents were randomly selected within each stratum. The study employed household-level surveys utilizing a semi-structured questionnaire to collect data at two distinct time points: pre-pandemic in 2019 and post-pandemic in 2022. In 2019, Southeast Asia, like much of the world, experienced the initial outbreak of the COVID-19 pandemic.

During this time, countries in Southeast Asia likely faced numerous challenges related to the spread of the virus, including healthcare strain, economic disruptions, and societal adjustments to new health protocols. The choice of 2022 as the endpoint for the study is significant because it signifies a period after concerted efforts were made to control and mitigate the impact of the pandemic. By 2022, countries in Southeast Asia likely implemented a range of public health measures, vaccination campaigns, and other interventions to curb the spread of the virus and manage its effects. Thus, by comparing 2022 to 2019, the study captures the potential lasting effects and changes in forest resource reliance resulting from the pandemic. The survey contents cover diverse aspects such as the extent of reliance on forest resources for livelihood activities, household characteristics, wealth composition, the significance of forestry resources to livelihoods, household members' efforts in obtaining forestry resources, non-timber alternatives for livelihoods, and the pandemic's impact on livelihoods and coping mechanisms.

2.3 Data analysis

The present study employed a mixed methods approach, integrating qualitative data from Participatory Rural Appraisal (PRA) to thoroughly examine participants' perceptions and attitudes regarding forest resources, forest dependence, the pandemic's impact on their livelihoods, and government support. Problem Tree Analysis is a central PRA technique used to identify, list, and prioritize problems faced by a community, along with their root causes and potential solutions (Chambers, 1994; Smita & Reddy, 2010). This visual tool not only helps communities recognize the interconnectedness of problems and their effects, but also facilitates the exploration of diverse solutions, making it particularly insightful for addressing complex issues like forest dependence within the context of a pandemic in our study (Sattler et al., 2022). The analysis of qualitative data was complemented by quantitative data obtained through a household survey, allowing for a comprehensive and detailed assessment of changes in forest dependence among local communities in pre-pandemic conditions in 2019 versus their post-pandemic situation in 2022.

To explore the determinants of changes in forest-resource use during the COVID-19 pandemic, we employed an ordered probit model to analyze the factors influencing

participants' self-assessment of their reliance on forest-related resources for their livelihoods. The variable of interest, the level of forest dependence, was treated as an ordinal variable, reflecting a categorical and ordered scale. This aligns with the manner in which the pertinent question was formulated in the survey questionnaires: "*Compared to the pre-pandemic period (before 2019), how do you rate, from 0 to 5, changes in your family's dependence levels on forest resources?*". The scale consisted of the following categories: No dependence (y=0), Significant decrease in dependence (y=1), Moderate decrease in dependence (y=2), No change in dependence (y=3), Moderate increase in dependence (y=4), Significant increase in dependence (y=5). Although the specific values of the ordinal variables are not significant, higher values are generally linked with higher outcomes. To simplify the discussion, we assume that the dependent variable has integer values of h = 1, 2, ..., 6. An underlying score is estimated in ordered probit models as a linear function of the independent variables and set of cut-off points.

Let y^*_i represent an unobservable variable that captures the level of livelihood dependence on forest-related resources of the i^{th} individual. The outcome can be expressed as a function of the vector of explanatory variables (x_i) and β being a vector of unknown parameters.

$$y^*_i = x_i'\beta + u_i \quad x_{ji} \text{where } u_i \sim N(0,1) \tag{1}$$

The selection of explanatory variables (X_i) was based on a review of the literature (De Queiroz et al., 2012; Estoque et al., 2019; FAO, 2020; Soe & Yeo-Chang, 2019; Ali et al., 2020; Nerfa et al., 2020; Troëng et al., 2020; Waruingi et al., 2021). Key independent variables represent the characteristics of households and household heads, poverty status, income sources, impact of the pandemic on households, and support from the government.

The probability of observing the outcome $y_j = h$, where $h = 1, 2, ..., 6$, is the likelihood that the linear function plus random error falls within the outcome cutoff point. We assume that y^*_i is related to y_i, and μ_j's are threshold parameters. These can be expressed as follows:

$y_i = 0$ ['No dependence'] if $-\infty < y^*_i < 0$

$y_i = 1$ ['Significant decrease in dependence'] if $0 \leq y^*_i < 1$

$y_i = 2$ ['Moderate decrease in dependence'] if $1 \leq y^*_i < 2$

$y_i = 3$ ['No change in dependence'] $2 \leq$ if $y^*_i < 3$

$y_i = 4$ ['Moderate increase in dependence'] if $3 \leq y^*_i < 4$

$y_i = 5$ ['Significant increase in dependence'] if $y^*_i \geq 4$ (2)

In general, the probability of observing outcome y_i is proportional to the probability that the estimated linear function plus the random error falls within the estimated cut-off points for the outcome.

$$\Pr(\text{outcome } y_j = h) = \Pr(\kappa_{h-1} < \beta_1 x_{1j} + \beta_2 x_{2j} + \cdots + \beta 5 x_{5j} + u_j \leq \kappa_h)$$

$$= \Phi(\kappa_h - x_j\beta) - \Phi(\kappa_{h-1} - x_j\beta) \tag{3}$$

where $x_j = (x_{1j}, x_{2j}, \ldots, x_{kj})$ are the k independent variables that model the mean function; β is a column vector of unknown parameters in the mean function; u_j, where $j = 1, \ldots, N$,

are normally distributed error terms; κ_h, where $h = 1, \ldots, 6$, are the unknown cutpoints that separate the different possible values of h; and $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution. Furthermore, to complete the intervals for the lowest and highest values of the outcome, $\kappa_0 = -\infty$ and $\kappa_{h+1} = \infty$.

The log-likelihood function is given as:

$$L = \sum_{i=1}^{n} \quad \sum_{j=0}^{5} \quad \partial_{ij} log_e{}^{k} [\, \Phi\, (\kappa_h \, - \, x_j\beta) \, - \, \Phi\, (\kappa_{h-1} - \, x_j\beta)] \quad (4)$$

where $\log_{e(\cdot)}$ denotes the natural logarithmic operator.

Inconsistencies and biases in ordered probit model estimates can arise due to heteroscedasticity. In the context of household forest dependence, the extent of reliance on forest-based income sources within the overall household income can lead to heteroscedasticity issues, as noted by Mamo et al. (2007) and Kamanga et al. (2009). To address such concerns, a Wald test was employed to examine heteroscedasticity in the regression model. The null hypothesis of the test assumes the absence of heteroscedasticity, while the alternative hypothesis assumes the presence of heteroscedasticity. The residuals of the model are used to compute the Wald statistic, and a statistical test, such as the chi-squared test, is used to determine whether the null hypothesis can be rejected in favor of the alternative hypothesis. A significant test result would suggest evidence of heteroscedasticity and the need for a corrected model, while a non-significant result would indicate that the homoscedastic model is sufficient. Thus, the heteroscedastic ordered probit model was also estimated as an alternative, which allows for the modeling of variance as a function of independent variables following Harvey (1976). The natural logarithm of the standard deviation is modeled as a linear combination of explanatory variables $ln\sigma_j = z_j\gamma$, where γ is a column vector of unknown parameters in the variance function.

The ordered probit function incorporating heteroscedasticity could be rewritten as:

$$Pr(yj= h) = \Phi \left\{\frac{\kappa h - xj\beta}{exp(zj)}\right\} - \Phi \left\{\frac{\kappa h-1 - xj\beta}{exp(zj)}\right\} \quad (5)$$

We estimated the coefficients $\beta_1, \beta_2, \ldots, \beta_k$ and $\gamma_1, \gamma_2, \ldots, \gamma_m$ together with the cutpoints $\kappa_1, \kappa_2, \ldots, \kappa_h$. Therefore, in this study, we report the estimated results of both the ordered probit model and heteroscedastic ordered probit model. Moreover, we used country dummy variables, with Vietnam as the base category to control for any country-specific effects. When analyzing the results of a statistical model, it is often crucial to calculate the marginal effects and report the estimated coefficients to offer a more intuitive understanding of how a specific factor affects the outcome of interest, such as changes in the degree of dependence on forests for livelihoods.

3. RESULTS

3.1 Characteristics of surveyed households

A comparison of household characteristics among surveyed households in Vietnam, Cambodia, and Laos is presented in Table 1. Notably, the average number of family members is a prominent feature, with households having an average of 5.5 members, 3.3 laborers, and 1.7 female laborers. Regarding poverty certification rates at the study sites in each country of Vietnam, Cambodia, and Laos, we observed the poverty rates of 60.1%, 33.3%, and 63.3%, respectively. Additionally, the distance from home to the nearest forests is assessed, with Vietnam recording 3.21 km, Cambodia at 7.11 km, and Laos at 2.38 km, averaging at 4.2 km. The findings reveal that, on average, households tend to be relatively small in size, possess a moderate number of laborers, and

experience relatively high poverty rates. Furthermore, there are notable variations in the distance to forests across the studied countries. The educational profile of household heads is also noteworthy, showing that 14.5% received no formal education, 52.3% completed primary education, 20.6% attained secondary education, 6.1% graduated high school, and 6.6% possess a college degree or higher qualification. These findings suggest that household heads in the surveyed region are generally older, predominantly male, and exhibit a moderate level of educational attainment. Importantly, variations in the educational levels of household heads are observed among the countries included in the study. These insights provide valuable information for understanding household dynamics and resource utilization in the context of forest-dependent livelihoods during the COVID-19 pandemic in Vietnam, Cambodia, and Laos.

Table 1. Characteristics of surveyed households

Variables	*Unit*	Vietnam	Cambodia	Laos	Average
Household characteristics					
Average no. of household members	*Persons*	6.1	5.3	5.2	5.5
Average no. of labors	*Persons*	3.5	3.1	3.3	3.3
Average no. of female labors	*Persons*	1.1	2.0	2.1	1.7
Poverty status	*%*	60.1	33.3	63.3	52.2
Average distance to nearest forests	*km*	3.21	7.11	2.38	4.2
Household head characteristics					
Average age	*Years*	42.1	39.9	47.1	43.0
Gender					
Male	*%*	86.7	90.0	96.7	91.1
Female	*%*	13.3	10.0	3.3	8.9
Education level					
Unschooled	*%*	6.7	16.7	20	14.5
Primary school	*%*	50.2	50.0	56.7	52.3
Secondary school	*%*	28.3	16.7	16.7	20.6
High school	*%*	11.7	3.3	3.3	6.1
College or higher	*%*	3.3	13.3	3.3	6.6
Main occupation					
Farmer	*%*	30.2	26.7	86.7	47.9
Non-farm business owner	*%*	1.7	3.0	6.7	3.8
Agricultural waged worker	*%*	31.3	3.3	0	11.5
Government staff	*%*	16.7	40	0	18.9
Others	*%*	10.1	27.0	3.3	13.5
Jobless	*%*	10.0	0	3.3	4.4

3.2 Forest-land use

Access to land is a crucial determinant of the extent of forest dependence among families, particularly in regions where forests serve as a vital source of livelihood and resources. The COVID-19 pandemic has intensified this reliance, given the disruptions to conventional income sources and supply chains caused by economic challenges and logistical issues. Consequently, families heavily reliant on forests for their livelihoods and resources may be more susceptible to the impacts of pandemics. In this context, it becomes pertinent to examine changes in family production land during the pandemic, especially for those employing forest-dependent livelihood strategies. The study's findings reveal a noteworthy increase in the proportion of land utilized for livelihood

activities compared to forests in each nation between 2019 and 2022 (as indicated in Table 2).

Table 2. Forest-land used by surveyed households (Unit: ha)

	Vietnam		Laos		Cambodia		Average	
	2022	2019	2022	2019	2022	2019	2022	2019
Forest	*1.17*	*1.16*	*2.96*	*2.18*	*0.66*	*0.47*	*1.47*	*1.22*
Natural forest	0	0	0.37	0.37	0	0	0.09	0.09
Managed forest	0.02	0.02	2.02	1.67	0	0	0.49	0.40
Plantations	1.15	1.14	0.57	0.14	0.66	0.47	0.89	0.73
Agricultural land	*0.46*	*0.43*	*2.21*	*2.25*	*1.30*	*1.30*	*1.08*	*1.07*
Paddy land	0	0	0.07	0.08	0.63	0.63	0.17	0.18
Cropland	0.46	0.43	1.42	1.44	0.67	0.67	0.72	0.71
Pasture (natural or planted)	0	0	0.38	0.38	0	0	0.10	0.10
Other agricultural lands	0	0	0.34	0.34	0	0	0.09	0.09
Other	*0.02*	*0.02*	*0.03*	*0.03*	*0.02*	*0.02*	*0.02*	*0.02*
TOTAL	1.65	1.61	5.20	4.46	1.97	1.78	2.57	2.32

Laos PDR exhibits a comparatively higher forest area per household in contrast to neighboring countries such as Vietnam and Cambodia. Over the period from 2019 to 2022, the total forest area per household in Laos experienced a rising trend from 2.18 hectares to 2.96 hectares. In the same timeframe, Cambodia recorded a forest area per household of 0.47 hectares in 2019, which slightly increased to 0.66 hectares in 2022. Conversely, Vietnam is expected to have the largest total production forest area in 2022, with 1.15 hectares per household. It is noteworthy that exclusively Laotian families possess natural forest lands, averaging 0.37 hectares per family. In contrast, natural forests in Vietnam and Cambodia are managed by government agencies. The observed increase in forested areas used between 2019 and 2022, amounting to 0.01 hectares, is approximately 0.25 times that of agricultural areas. This suggests a potential escalation in dependence on forests during the pandemic.

Using the PRA approach, we synthesized the relationship between forest-resource use and the pandemic in three problem trees (see Appendix 3). In all three cases, the COVID-19 pandemic disrupted traditional livelihoods, leading to an increased reliance on forest resources. This over-reliance has several negative impacts, including threatened biodiversity, reduced forest resources, and threatened sustainable development. In addition, they highlight the importance of diversifying income sources, promoting sustainable agricultural practices, and implementing measures to conserve forest resources. They also emphasize the need for policies and interventions that can address these root causes and mitigate their impacts. For example, in Vietnam, the problem tree shows the consequences of increased forest-dependence to include threatened forest ecosystem diversity, reduced forest resources, reduced communities' resilience, and threatened sustainable development of rural society.

In Laos, the problem tree illustrates the causes and effects of increasing forest dependence in Nam Kading Protected Area. The causes include forests being cut for charcoal production and firewood, farming leading to declining forestland quality, conversion of forests and mountain landscapes to settlement and farming, overexploitation of forests, and immigration leading to illegal poaching and land grabbing. In Cambodia, the finding indicates increasing forest dependence that could lead to illegal logging, poaching, unsustainable Non-Timber Forest Products (NTFP) extraction, and farmland expansion. Consequently, this has led to a rise in agricultural

and forestry activities.

This study revealed significant variations in land ownership for agricultural production among Vietnamese, Lao, and Cambodian households. On average, Vietnamese households possessed the smallest agricultural land, with 1.65 hectares per family, while Lao households had the largest, with an average of 5.20 hectares per household. These disparities reflect distinct regulations and approaches to utilizing agricultural land to augment household income in the Southeast Asian countries of Vietnam, Laos, and Cambodia.

3.3 Income generation activities

The data on annual household income from diverse sources in Vietnam, Laos, and Cambodia for the years 2022 and 2019 is presented in Figure 2 and Table 3, using USD as the unit of measurement.

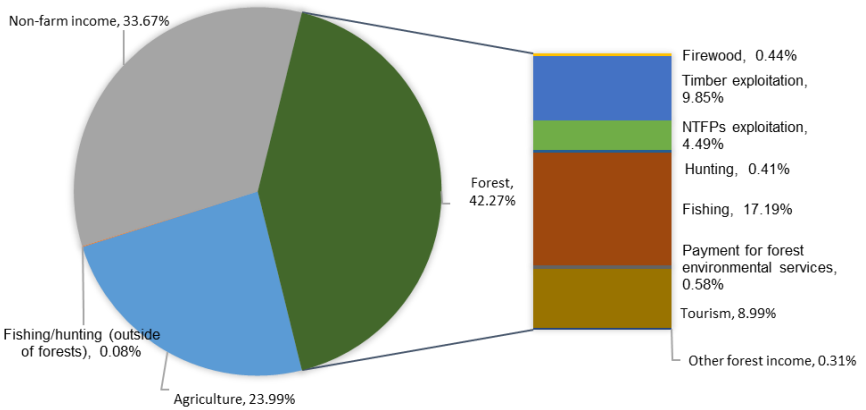


Figure 2. Overall income composition of surveyed households in three countries in 2022

The table provides a comprehensive breakdown of income from various sources, encompassing agriculture, crops, livestock, aquaculture, forest-related activities such as firewood, timber exploitation, non-timber forest products (NTFPs) exploitation, hunting, fishing, forest environmental services payment, tourism, and other sources. The average household income across the three countries in 2022 is reported as 3,438.6 USD, while in 2019 it was 3,011.2 USD. Further analysis reveals that Vietnam exhibited the highest income from agriculture, crops, and aquaculture, while Laos recorded the highest income from livestock. Conversely, Cambodia demonstrated the highest income from fishing, tourism, and forest environmental services payment (FESP). Of particular significance, the income derived from forest resources was found to be the highest in Cambodia and the lowest in Vietnam for both the years under consideration.

Moreover, the data indicates that off-farm income exhibited higher levels in Laos and Cambodia compared to Vietnam. These outcomes underscore the disparities in income sources prevalent across the Indochina region, signifying distinct strengths and challenges in each country's economic landscape. The findings carry significant implications for policymakers and practitioners involved in promoting sustainable livelihoods and advocating for equitable resource distribution within the region.

The study's findings highlight notable variations in family income sources in Vietnam, Laos, and Cambodia, as illustrated in Figure 2. Forest resources are projected to constitute a significant proportion of total income for Vietnamese households, expected to reach approximately 40% by 2022. In contrast, Cambodian households

heavily rely on forests, with forests contributing as much as 73% to their overall income. Conversely, Lao families derive a smaller portion of their income from forests, around 20%, while a substantial portion of their income (approximately 52%) is generated through agricultural activities. We observed a significant increase in household income derived from forest-based activities between 2019 and 2022, approximately 112.1%, 28.7%, and 1.68% respectively for Vietnam, Cambodia, and Laos. Vietnamese and Cambodian families exhibit a comparatively lower dependence on agriculture, with projected income shares of only 23% and 8%, respectively. Non-farm income sources also hold substantial importance for families in these countries, contributing around 30% to their total income in each case. To sustain their livelihoods and maintain their quality of life, families in these regions employ diverse income generation strategies, with revenue from forest-based activities playing a crucial role in the overall income of forest-dependent households. Consequently, any shifts in family livelihood choices, particularly in response to factors like a pandemic, could potentially lead to a heightened reliance on forest resources for their well-being and economic sustenance.

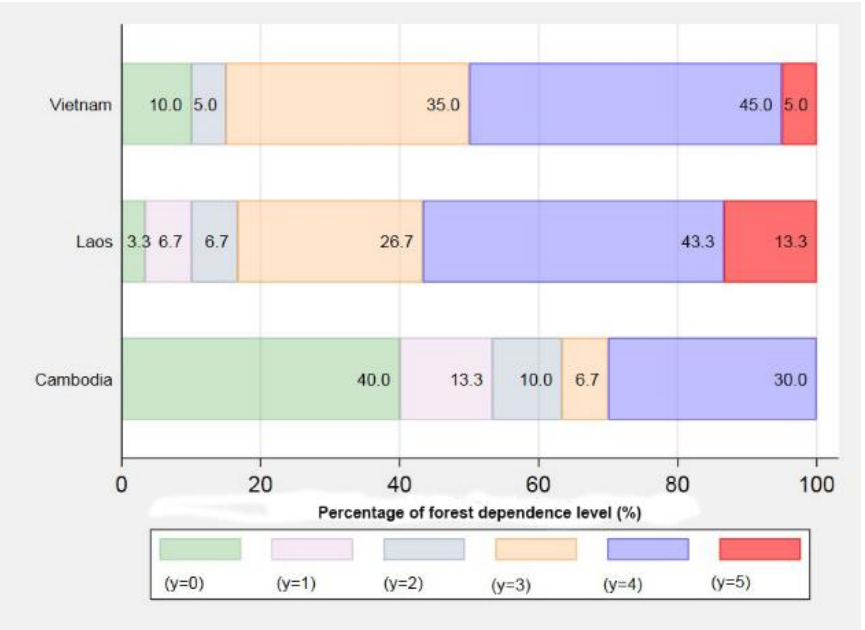
Table 3. Annual income of surveyed households from different livelihood activities by countries (per household in $USD as of 2022)

	Vietnam		Laos		Cambodia		Average	
	2022	2019	2022	2019	2022	2019	2022	2019
Agriculture	*597.3*	*370.2*	*2027.5*	*741.8*	*411.4*	*358.7*	*908.4*	*460.2*
Crops	290.1	226.5	829.7	381.4	135.5	142.2	386.3	244.1
Livestock	307.2	143.7	1194.1	360.5	77.2	76.9	471.5	181.2
Aquaculture	0	0	3.8	0	198.7	139.6	50.6	34.9
Forest	*1039.8*	*490.1*	*624.2*	*484.7*	*3700.3*	*3638.9*	*1601.0*	*1276.0*
Firewood	0.0	0.0	66.9	66.6	0	0	16.7	16.7
Timber exploitation	746.4	165.2	0.0	0.0	0	0	373.2	82.6
NTFPs exploitation	232.6	258.1	170.2	167.8	44.9	44.9	170.1	182.2
Hunting	31.2	37.2	0.5	0.5	0	0	15.7	18.7
Fishing	2.2	2.2	363.9	249.8	2235.7	2186.4	651.0	610.1
FESP	27.5	27.5	0	0	32.8	32.8	21.9	21.9
Tourism	0	0	0	0	1362.2	1350.1	340.5	337.5
Others	0	0	22.6	0	24.6	24.6	11.8	6.2
Fishing/hunting (outside of forest areas)	*5.8*	*5.8*	*0*	*0*	*0*	*0*	*2.9*	*2.9*
Off-farm income	*1004.5*	*1248.0*	*1233.6*	*1650.0*	*954.4*	*954.4*	*929.2*	*1275.0*
TOTAL	2641.6	2108.4	3885.2	2876.5	5066.1	4952.0	3438.6	3011.2

3.4 Changes in the level of dependence on forest resources during COVID-19

The primary aim of this research was to assess changes in the degree of forest resource dependence among families in the surveyed countries by self-evaluating their reliance on these resources during the COVID-19 pandemic in comparison to pre-pandemic periods. The study findings revealed a notable level of forest dependence in the surveyed regions when compared to the reference year of 2019 (as depicted in Figure 3). Specifically, approximately half of the respondents in Vietnam, 57% in Laos, and 30% in Cambodia reported experiencing moderate to substantial increases in their reliance on forest-related resources. These results highlight that a considerable number of surveyed families continue to heavily depend on forests for their livelihoods, relying significantly on the resources provided by forest ecosystems. During a pandemic, local communities will rely on forest-related resources to cope with shortages (e.g. food, medicine, wood as cooking fuels) resulting from pandemic

restrictions. This finding reinforces the well-documented safeguarding role of forests in supporting forest-dependent communities, as emphasized in recent existing literature. For instance, Nunan et al. (2022) demonstrates that forests can produce substantial livelihood benefits, both tangible and intangible in nature. In addition, Maraseni et al.'s (2022) evaluation of the COVID-19 influence on Nepal's forestry sector observed that smallholders adopted various livelihood alternatives to sustain their livelihoods during the pandemic.



Note: No dependence (y=0); Significant decrease in dependence (y=1); Moderate decrease in dependence (y=2); No change in dependence (y=3); Moderate increase in dependence (y=4); Significant increase in dependence (y=5).

Figure 3. Self-assessment on changes in forest dependence level compared with pre-pandemic

3.5 Factors affecting changes in the level of dependence on forest resources

The estimated results of the ordered probit model and the heteroscedastic ordered probit model, which were employed to examine the factors influencing respondents' assessment of changes in their dependence on forest-related resources for their livelihoods are presented in Table 4. Given the reasonable assumption that a household's reliance on forests is linked to the contribution of forest income to its overall livelihood, the extent of dependence on forest resources may vary significantly among households that place greater emphasis on income generated from forest sources (Mamo et al., 2007; Kamanga et al., 2009). To explore the potential increase in variation in the level of dependence on forest resources due to households' self-assessment of the importance of forest income to their livelihood, both homoscedastic and heteroscedastic ordered probit models were employed in this analysis. The adoption of both models enabled a more comprehensive understanding of the factors influencing the level of forest resource use and dependence among households, considering the nuanced variations in their reliance on forest-related income. This approach contributes to a deeper insight into the complex dynamics of forest resource utilization and its determinants in the context of the COVID-19 pandemic, particularly

among rural households living in protected areas of Vietnam, Laos, and Cambodia.

The Wald test of heteroscedasticity is employed to examine whether the variance of the error term varies significantly across different categories of the dependent variable - the level of livelihood dependence on forest resources. A statistically significant test outcome indicates notable heterogeneity in the error term's variance, rendering the heteroscedastic ordered probit model a more appropriate fit than the standard ordered probit model. The chi-squared test statistic yields a value of chi2(1) = 27.44, with Prob > chi2 = 0.0000, signifying the presence of heteroscedasticity in the estimated model assessing the significance of forest income. Consequently, we utilize the heteroscedastic ordered probit model, represented by Equation (3), as the primary estimation tool. To validate the robustness of our findings, we also employ the ordered probit model, represented by Equation (2). Both models were estimated using maximum likelihood estimation procedures in STATA software, employing the orprobit and hetorprobit functions.

Table 4. Estimated coefficients of the ordered probit model and heteroskedastic ordered probit model for determinants of changes in the level of livelihood dependence on forest resources

Variables	Ordered probit model (1)		Heteroskedastic ordered probit model (2)	
	Coefficients	S.E.	Coefficients	S.E.
Age (year)	0.006	-0.017	-0.095	-0.074
Gender (Male=1)	0.178	-0.398	1.757	-1.277
Minority group (yes=1)	0.721**	-0.338	6.486**	-2.91
Education (year)	0.060**	-0.029	0.102	-0.091
Household size (person)	0.158*	-0.084	0.547	-0.531
Women labor (person)	-0.303	-0.195	0.34	-0.528
Poverty status (yes=1)	0.661***	-0.245	2.823**	-1.203
Year live (year)	0.001	-0.013	0.128*	-0.075
Distance to forest (km)	0.096***	-0.036	0.275	-0.216
On-farm income (%)	-0.355	-0.649	-3.706	-2.301
Forest income (%)	8.500***	-1.587	9.137*	-5.19
Livelihood change (yes=1)	0.958**	-0.409	4.205	-3.558
COVID positive case (yes=1)	0.26	-0.275	1.611	-1.18
Assessment on COVID impact (negative=1)	0.697***	-0.176	1.611**	-0.807
COVID support received (yes=1)	-2.088**	-1.004	-2.871*	-1.71
Assessment on effectiveness of support (positive=1)	1.49	-1.079	5.544	-5.089
Country dummy 1	2.595**	-1.148	9.296*	-5.579
Country dummy 2	3.098***	-1.092	9.666*	-4.974
Importance of forest income			0.735***	-0.14
Log-likelihood		-110.3457		-97.0325
Wald test of heteroskedasticity			chi2(1) = 27.44; Prob > chi2 = 0.0000	
Observations	270			

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Country dummy, base is Vietnam.

Table 4 presents crucial insights into the relationship between the explanatory variables in our model and the outcome variable of interest, namely the level of dependence on forest resources for livelihood. The explanatory variables, comprising minority group status, poverty status, income from forests, and receipt of COVID-19 relief, exhibited significant associations with the extent of forest reliance. Specifically, belonging to a minority group and being identified as economically disadvantaged by

local authorities were positively correlated with a higher degree of dependence on forest resources for livelihoods. The observed associations underscore the importance of considering social and economic factors in understanding the dynamics of forest resource use among rural households during the COVID-19 pandemic.

In this study, we observed that households heavily reliant on forest resources for their income and facing adverse impacts from the COVID-19 pandemic exhibited higher levels of forest dependence. The findings presented here are consistent with the results of Golar et al. (2020), which also highlighted the significant challenges of deforestation and land-use change during the pandemic. In addition, households that received COVID-19 aid showed potential indications of lower reliance on forest resources. We estimated the marginal effects for the ordered probit model (see Appendix 4) and the heteroscedastic ordered probit model (see Appendix 5). Overall, we found significant factors associated with a heightened level of dependence on forest resources in the ordered probit model. These factors include membership in a minority group, higher education levels, classification as impoverished by local authorities, proximity to forests, a larger proportion of income derived from forest-based activities, experiencing a shift in livelihood due to the COVID-19 pandemic, and holding a negative perception of the pandemic's impact. Interestingly, higher education is likely to contribute to a better understanding of forest resources, opening up possibilities for alternative income generation and the diversification of livelihood activities (Garekae et al., 2017; Kien et al., 2023).

Specifically, individuals belonging to minority groups are found to have an increased likelihood of exhibiting high forest resource dependence. Additionally, those who rely more heavily on income from forest-related activities are also more likely to demonstrate a greater level of dependence on forest resources. Furthermore, the study shows that household classified as ‘poor’ by local authorities are associated with a higher probability of experiencing a high level of dependence on forest resources. The results outlined in Appendix 5 concerning the heteroscedastic ordered probit model reveal the existence of supplementary variables - beyond those detailed in Appendix 4 - that exert a significant influence on individuals' dependence on forest-derived resources for their livelihoods. It is noteworthy, however, that in the case of household size, there is no longer significant evidence to support its impact. Particularly noteworthy is the observed correlation between the length of residency in the region, the presence of a COVID-positive case within the household, and the level of income generated through agricultural activities, all of which were linked to varying degrees of dependence on forest resources.

4. CONCLUSION

The study examined the extent of forest reliance for livelihoods and identifies key drivers behind changes in forest-resource use by local communities residing in protected areas of Vietnam, Laos, and Cambodia amidst the COVID-19 pandemic. The study findings indicate that local communities in the research areas rely heavily on forest-related resources for their livelihoods, with a substantial portion of household income stemming from forest-based occupations. Moreover, the study reveals an upsurge in forest dependence during the pandemic period, emphasizing the safeguarding role of forests in the economies of communities residing near protected regions. This phenomenon also suggests that people tend to exploit forestry resources as safeguarding mechanisms for external shocks. The study identifies several significant factors driving changes in forest dependence, including income from forests, poverty levels, minority group status, and receipt of COVID-19 relief. The inclusion of

Vietnam, Laos, and Cambodia in this analysis is expected to enhance our understanding of the drivers of forest dependence and associated socio-economic issues during the COVID-19 pandemic.

Current knowledge regarding the factors affecting forest dependence in Southeast Asia during the pandemic remains limited. Therefore, the evidence-based insights derived from this study are crucial for policymakers and practitioners to effectively address the challenges posed by the pandemic, reduce reliance on forests, promote community resilience, and ensure sustainable forest management. Furthermore, it is crucial to emphasize that the heightened use of forest resources during the pandemic may result in forest degradation and illegal logging. Therefore, it is imperative to prioritize viable alternative solutions to enhance the livelihoods of local communities in the central policy agenda. By addressing these challenges proactively, we can ensure the sustainable utilization of forest resources while safeguarding the well-being of forest-dependent communities.

We acknowledged the limitations of this study, which collected data from a relatively small sample size in only three countries situated within the Indochina Peninsula. Hence, while the findings cannot be universally applied to the entire region, they can serve as valuable entry points for targeted policy interventions within specific contexts. Additionally, the reliance on self-reported data may have introduced potential sources of bias and inaccurate reporting as we measured the perception about the level of livelihood dependence on forest resources, but not the real change data. Furthermore, the study did not investigate the long-term implications of the pandemic on forest-dependent communities or the sustainability of forest management in the region. Moreover, external factors such as climate change and natural disasters, which may affect forest dependence and management, were not considered in the study. Consequently, a more comprehensive and integrated approach is necessary to gather evidence-based information that can assist policymakers and practitioners in aiding local communities in managing the challenges of future risks and uncertainties.

Author Contributions: Nguyen Duc Kien, Nguyen Cong Dinh, Le Thanh An: Conceptualization, Supervision, Formal analysis. Nguyen Cong Dinh, Le Thanh An: editing and revising.

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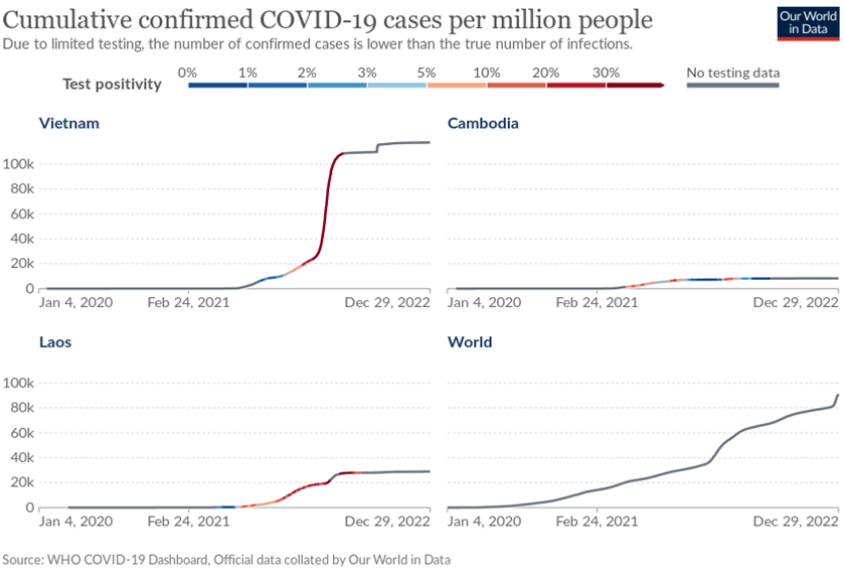
APPENDIX

Appendix 1: Situation of COVID-19 outbreaks in Vietnam, Laos, Cambodia, and the World (2020-2022)



Appendix 2: Characteristics of selected study sites

Study sites	Founded in	Areas (ha)	Brief descriptions
Phong Nha - Ke Bang National Park, Vietnam	2001	123,326	○ Managed by Quang Binh Provincial People's Committee ○ 85.754 ha of core zone is a World Nature Heritage Site since 2003 ○ Limestone plateaus and tropical forests ○ Great geological diversity and intense human–forest interactions
Nam Kading Protected Area, Laos	1993	169,000	○ Third largest protected area and one of Laos's most important natural ecosystems ○ 80% of Bolikhamxay's population lives off forest production, particularly hunting and non-timber forest products (NTFPs) collection. ○ New plantations and agricultural development are increasing PA land use conflicts.
Virachey National Park, Cambodia	1993	33,500	○ Cambodia's largest and most important conservation area. ○ One of two Cambodian ASEAN Heritage Parks; diverse natural habitats

Appendix 3: Results of Focus Group Discussions

FGDs at the study sites indicated important issues regarding forest dependence and the livelihoods of communities surrounding the protected areas. The findings from the discussions of the three countries are mapped onto the problem trees as shown in Figures below.

Vietnam

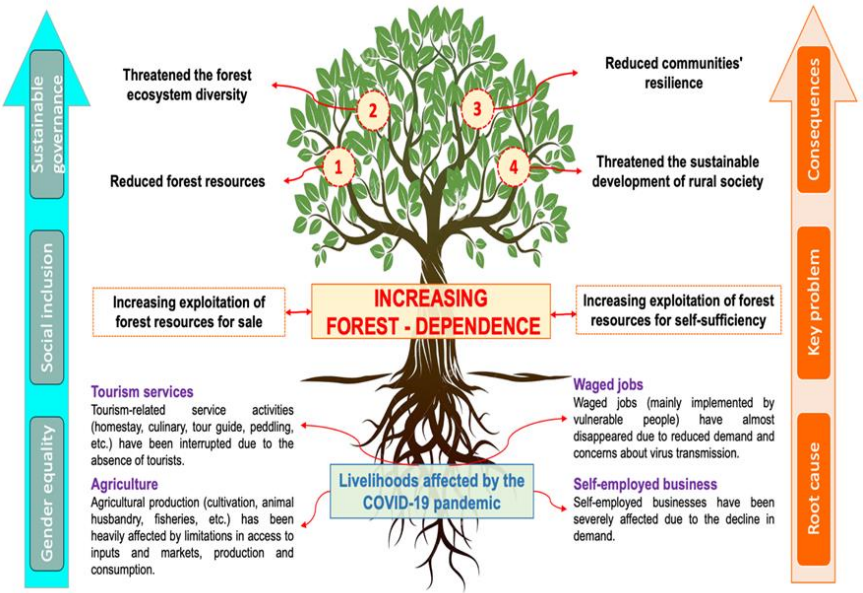


Figure 3a. Problem tree for Phong Nha – Ke Bang National Park, Vietnam

Cambodia

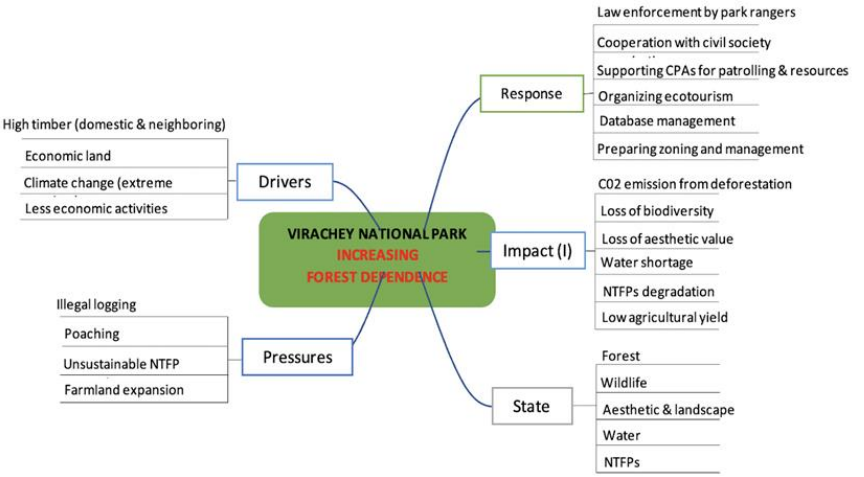


Figure 3b. Problem tree for Virachey National Park, Cambodia

Laos

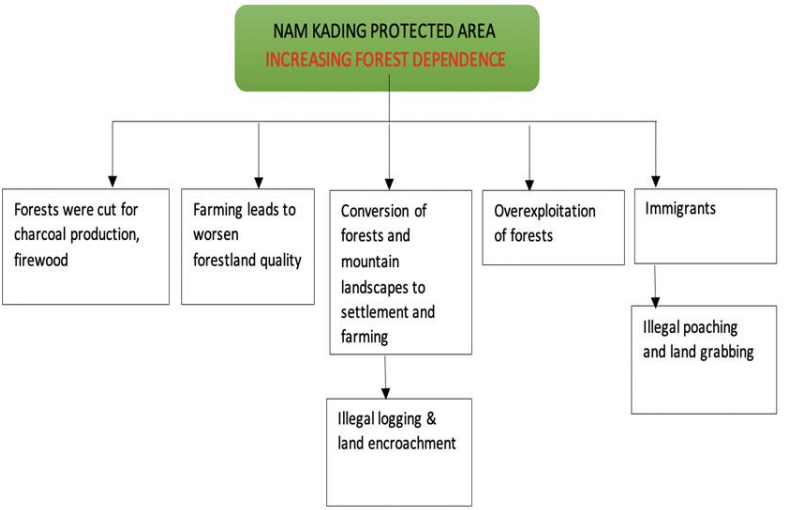


Figure 3c. Problem tree for Nam Kading Protected Area, Laos

Appendix 4: Marginal effects on factors affecting the probability of forest-resource dependence using the ordered probit model

Level of dependence	No dependence (y=0)		Significant decrease in dependence (y=1)		Moderate decrease in dependence (y=2)		No change in dependence (y=3)		Moderate increase in dependence (y=4)		Significant increase in dependence (y=5)	
	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.
Age (year)	-0.001	0.002	0	0	0	0	0	0	0.001	0.002	0	0.001
Gender (Male=1)	-0.023	0.052	-0.005	0.011	-0.005	0.011	-0.002	0.006	0.022	0.049	0.013	0.029
Minority group (yes=1)	-0.095*	0.045	-0.019	0.012	-0.018	0.011	-0.009	0.012	0.089*	0.04	0.053*	0.027
Education (year)	-0.008*	0.004	-0.002*	0.001	-0.002*	0.001	-0.001	0.001	0.007	0.004	0.004	0.002
Household size (person)	-0.021*	0.011	-0.004*	0.003	-0.004	0.003	-0.002	0.003	0.020*	0.01	0.012*	0.007
Women labor (person)	0.04	0.025	0.008	0.006	0.008	0.006	0.004	0.006	-0.037	0.024	-0.022	0.015
Poverty status (yes=1)	-0.087**	0.034	-0.017*	0.01	-0.017**	0.009	-0.009	0.012	0.082***	0.031	0.048**	0.02
Year live (year)	0	0.002	0	0	0	0	0	0	0	0.002	0	0.001
Distance to forest (km)	-0.013***	0.005	-0.003*	0.001	-0.002*	0.001	-0.001	0.002	0.012***	0.005	0.007**	0.003
On-farm income (%)	0.047	0.085	0.009	0.018	0.009	0.017	0.005	0.011	-0.044	0.08	-0.026	0.047
Forest income (%)	-1.119***	0.243	-0.224**	0.105	-0.217	0.095	-0.111	0.142	1.051***	0.233	0.620***	0.15
Livelihood change (yes=1)	-0.126*	0.057	-0.025	0.016	-0.025*	0.013	-0.012	0.016	0.118**	0.051	0.070**	0.033
COVID positive case (yes=1)	-0.034	0.036	-0.007	0.008	-0.007	0.007	-0.003	0.006	0.032	0.034	0.019	0.02
Assessment on COVID impact (Negative=1)	-0.092***	0.025	-0.018*	0.009	-0.018**	0.008	-0.009	0.012	0.086***	0.025	0.051***	0.015
COVID support received (yes=1)	-0.275	0.129	0.055	0.035	0.053	0.029	0.027	0.042	0.258	0.13	0.152	0.079
Assessment on effectiveness of support (positive=1)	-0.196	0.138	-0.039	0.037	-0.038	0.031	-0.019	0.026	0.184	0.131	0.109	0.08
Country dummy 1	-0.342*	0.153	-0.068	0.043	-0.066*	0.036	-0.034	0.049	0.321*	0.149	0.189*	0.092
Country dummy 2	-0.408***	0.137	-0.082*	0.045	-0.079*	0.039	-0.04	0.06	0.383***	0.144	0.226**	0.094

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix 5: Marginal effects on factors affecting the probability of forest-resource dependence using the heteroskedastic ordered probit model

Level of dependence	No dependence (y=0)		Significant decrease in dependence (y=1)		Moderate decrease in dependence (y=2)		No change in dependence (y=3)		Moderate increase in dependence (y=4)		Significant increase in dependence (y=5).	
	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.
Age (year)	0.005	0.003	-0.001	0.001	-0.001	0.001	-0.001	0.001	-0.002*	0.001	-0.001*	0
Gender (Male=1)	-0.092	0.061	0.015	0.013	0.025	0.02	0.014	0.018	0.028	0.021	0.01	0.008
Minority group (yes=1)	-0.338***	0.092	0.055	0.056	0.092*	0.049	0.051	0.049	0.103***	0.031	0.036***	0.014
Education (year)	-0.005	0.005	0.001	0.001	0.001	0.002	0.001	0.001	0.002	0.002	0.001	0.001
Household size (person)	-0.028	0.031	0.005	0.005	0.008	0.01	0.004	0.006	0.009	0.01	0.003	0.004
Women labor (person)	-0.018	0.025	0.003	0.005	0.005	0.007	0.003	0.004	0.005	0.007	0.002	0.003
Poverty status (yes=1)	-0.147***	0.046	0.024	0.024	0.040*	0.021	0.022	0.022	0.045***	0.017	0.016*	0.007
Year live (year)	-0.007*	0.003	0.001	0.001	0.002*	0.001	0.001	0.001	0.002***	0.001	0.001**	0
Distance to forest (km)	-0.014	0.009	0.002	0.003	0.004	0.003	0.002	0.003	0.004*	0.002	0.002*	0.001
On-farm income (%)	0.193*	0.098	-0.032	0.034	-0.053	0.036	-0.029	0.033	-0.059**	0.028	-0.021*	0.011
Forest income (%)	-5.008***	1.418	0.819	0.773	1.367*	0.709	0.759	0.839	1.528***	0.417	0.537***	0.128
Livelihood change (yes=1)	-0.219	0.149	0.036	0.042	0.06	0.048	0.033	0.043	0.067*	0.042	0.023*	0.015
COVID positive case (yes=1)	-0.084*	0.044	0.014	0.014	0.023*	0.013	0.013	0.016	0.026*	0.015	0.009*	0.005
Assessment on COVID impact (Negative=1)	-0.084*	0.038	0.014	0.016	0.023	0.013	0.013	0.011	0.026*	0.014	0.009*	0.005
COVID support received (yes=1)	-0.15	0.084	0.024*	0.026	0.041*	0.032	0.023*	0.024	0.046*	0.026	0.016*	0.011
Assessment on effectiveness of support (positive=1)	-0.289	0.258	0.047	0.065	0.079	0.076	0.044	0.051	0.088*	0.084	0.031*	0.031
Country dummy 1	-0.484*	0.217	0.079	0.08	0.132	0.088	0.073	0.082	0.148*	0.06	0.052*	0.025
Country dummy 2	-0.504***	0.178	0.082	0.078	0.137*	0.082	0.076	0.082	0.154***	0.058	0.054*	0.023
Importance of forest income	0.039***	0.008	-0.01	0.01	-0.005***	0.01	-0.044***	0.01	-0.021*	0.012	0.040***	0.008

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

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