

What Factors Promote Peatland Fire Prevention?
Evidence from Central Kalimantan, Indonesia

Yuki Yamamoto

Graduate School of Economics, Kobe University
Rokko, Kobe 657-8501, Japan

Kenji Takeuchi¹

Graduate School of Economics, Kobe University
Rokko, Kobe 657-8501, Japan

Gunnar Köhlin

Department of Economics, the University of Gothenburg

¹Corresponding author. takeuchi@econ.kobe-u.ac.jp

Abstract

This study investigates the factors that promote peatland fire prevention in Central Kalimantan, Indonesia. We focus on Kalimantan Forests and Climate Partnership (KFCP) as one of the earliest pilot projects to reduce emissions from deforestation and degradation (REDD). We estimate an agricultural labor allocation model by combining household survey data and satellite information. The results suggest that the impact of KFCP on household decision making concerning fire prevention at agricultural plots is statistically insignificant. This can be attributed to the fact that the KFCP has not changed the incentives for household fire prevention at individual plots. Economic factors such as the value of labor allocation for rubber production and exogenous income as well as non-economic factors such as traditional mutual assistance, called *Goton-royong*, are statistically significant. These results suggest that an appropriate design for intervention would be a combination of economic and non-economic incentives to achieve effective REDD policy.

1 Introduction

Reducing Emissions from Deforestation and Degradation (REDD) has been a focus of international discussion as an efficient climate change policy. The basic function of REDD is to offer developing countries an opportunity for financial support from developed countries in response to avoiding carbon emissions through forest conservation thereby reducing the conflict between developed and developing nations regarding global warming negotiations. Deveny et al. (2009) assess the capacity for implementing REDD in each country using the Forest Carbon Index (FCI). They give Indonesia a high evaluation along with Brazil, Russia, Peru, Bolivia, and Colombia.

One of the key issues for implementing REDD in Indonesia is the high risk of peatland fire. Forestland in Central Kalimantan, Indonesia is composed of thick peat swamp and 2,000-6,000 metric tons of carbon per hectare (t C/ha), compared to the average 225 t C/ha in moist tropical forests in southeast Asia (Page et al., 1999; IPCC, 2006). Once peat has been ignited, the burning of its organic-rich materials is hard to put out and it releases its carbon into the atmosphere. For example, during a large-scale peatland fire in 1997, the total carbon dioxide emission from Indonesia was estimated to be between 0.81 and 2.57 gigatons, which is equal to 13–40 percent of the mean annual global carbon emissions from fossil fuels (Page et al., 2002). The combination of

fire and the vast amount of carbon released made Indonesia the third largest Greenhouse Gas (GHG) emitter in the world (Myers Madeira, 2008).

In 2008, the governments of Indonesia and Australia jointly announced the Kalimantan Forest Carbon Partnership (KFCP), one of the world's first REDD pilot projects. The project aimed to reduce GHG emissions from deforestation and peatland fires by involving farmers in fire prevention and reducing the use of fire at individual plots. With a significant budget, KFCP was expected to be effective REDD. However, the impact of the project is currently unclear, and has yet to be thoroughly evaluated. The results obtained by our analysis suggest that KFCP might not have offered appropriate incentives for farmers to promote fire prevention behavior at individual plots.

While fire prevention is an important aspect of forest and climate policy, it has not been seriously addressed in economic literature. An exception is Bowman et al. (2008) who investigated household decision making concerning fire prevention in the Brazilian Amazon. They explored the factors that affected household decisions on fire prevention and found that economic factors (e.g., the value of labor allocation for agriculture) plays a significant role in promoting individual fire prevention. As the value of labor allocation to agriculture increases, households become more productive in crop production; hence, there is a greater expected benefit of fire prevention.

This study extends prior research by estimating a household labor allo-

cation model. The main contributions of this study are as follows. Firstly, we evaluated the impact of the KFCP project and found that this program was insufficient to change household decisions on fire prevention. KFCP was one of the earliest of the 15 REDD pilot projects undertaken throughout the world prior to 2009 (Carlson, 2009). While some studies have addressed the consequences of REDD pilot projects using descriptive approach (Resosudarmo et al., 2012; Olbrei and Howes, 2012), there are no studies that evaluate the impact of REDD pilot projects at the household level using an econometric analysis. Secondly, we estimated the household labor allocation model by combining data from the household survey with global NASA/MODIS satellite data. Satellite information is useful for considering fire risk objectively and investigating fire prevention comprehensively. In our analysis, the number of hot spots observed by satellite is used as a variable explaining the degree of fire risk. Thirdly, we hypothesized that social factors, not only economic factors, play an important role in fire prevention. We focused on the mutual assistance custom called *Gotong-royong* as being an important factor in the decision making regarding household labor allocation for fire prevention. *Gotong-royong* includes a wide range of group activities in the community, such as providing labor to clear agricultural plots, the construction and repair of public infrastructure, guarding the village, and financial support. This behavior provides the community with social norms

and serves as a determinant of social capital based on the norms that are generally observable in urban and rural Indonesia (Bowen, 1986).

Recent studies on development recognize the importance of social capital in the self-governance of common property resources (Ostrom, 1990). Indonesia is a suitable place to evaluate the impact of social capital on REDD schemes because households have traditionally been involved in the community through *Gotong-royong*. Policy makers in Indonesia have noted the importance of *Gotong-royong* on social improvement, and have used this involvement to improve health care, education, sanitation and financial support (Wibisana et al., 1999). Since the effect of fire prevention behavior depends in part on the behavior of neighbors, it is important to take into account the relationships within the community. While many studies have considered the role of social capital in development and environmental policy (Feigenberg, 2010; Sujarwoto, 2013), no studies have examined its effect in the context of REDD.

2 Household model

We develop a subsistence household model to determine the factors that encourage households to allocate their time for fire prevention. Households are assumed to allocate family labor for rice cultivation, rubber cultivation,

off-farm work, fire prevention, and leisure (Beukering, 2008; Yamamoto and Takeuchi, 2012). In our model, a household is both a producer and a consumer of agricultural goods, and thus, labor allocation depends mainly on consumption needs (Fisher et al., 2005). Households have a quasi-concave utility function:

$$\max_{C_r, C_m, l} U = U(C_r, C_m, l; \Omega), \quad (1)$$

where C_r , C_m , l , and Ω are the consumption of rice, that of composite purchased goods, that of leisure time, and the household's characteristics, respectively. The utility is maximized subject to the production functions for rice, rubber and off-farm work, a full income constraint, a time constraint, and non-negativity constraints:

$$Q_r = Q_r(L_r, K_r; \Omega), \quad (2)$$

$$Q_g = Q_g(L_g, K_g, L_p; \Omega), \quad (3)$$

$$Q_o = Q_o(L_o; \Omega), \quad (4)$$

$$Y = P_r(Q_r - C_r) + P_{gj}Q_g + P_oQ_o - P_mC_m, \quad (5)$$

$$l = T - L_r - L_g - L_o - L_p, \quad (6)$$

$$C_r, C_m, l, Q_r, Q_g, Q_o, L_r, L_g, L_p, L_o \geq 0. \quad (7)$$

Equations (2) and (3) describe, respectively, the production of rice and rubber, which are assumed to be functions of labor (L_r and L_g), capital (K_r and

K_g), household characteristics (Ω), and, for rubber production, labor input for fire prevention (L_p). Households can reduce their risk of fire damage and increase the associated benefit of rubber production by allocating labor for fire prevention. Fire prevention (L_p) does not enter into the production function for rice because households in this area have adapted to the risk of fire, changing their period of cultivation to avoid fire damage. They have less risk of fire in the rainy season (from October to March) and typically cultivate rice in this period.

Equation (4) describes the off-farm work function requiring labor input (L_o).² We assume that the production functions for rice $Q_r(\cdot)$, rubber $Q_g(\cdot)$, and off-farm work $Q_o(\cdot)$ have decreasing returns to scale. Equation (5) describes a household's full income constraint. A household can be either a net seller or buyer of rice ($Q_r > C_r$ or $Q_r < C_r$). Households sell their rubber crops at the local price P_{gj} , but do not buy any rubber crops. They can also earn P_o by allocating off-farm work Q_o . Households buy composite goods (C_m) at market price (P_m). Equation (6) describes a household's time constraint.

The Lagrangian of the household's maximization problem is represented

²We define off-farm work here as work hours spent outside of ones' own agricultural plot. This includes working on the another's plot, hunting, logging, driving boats or motorcycles, construction and working for the KFCP project.

as

$$\begin{aligned}
\mathcal{L} &= U(C_r, C_m, l; \Omega) \\
&- \lambda \{ Y - P_r(Q_r(L_r, K_r; \Omega) - C_r) - P_{gj}Q_g(L_g, K_g, L_p; \Omega) \\
&- P_oQ_o(L_o; \Omega) + P_mC_m \} + \gamma(T - L_r - L_g - L_o - L_p). \tag{8}
\end{aligned}$$

The first-order conditions can be derived as

$$\frac{\partial \mathcal{L}}{\partial L_p} = \lambda P_{gj} \frac{\partial Q_g}{\partial L_p} - \gamma = 0, \tag{9}$$

$$\frac{\partial \mathcal{L}}{\partial L_o} = \lambda P_o \frac{\partial Q_o}{\partial L_o} - \gamma = 0, \tag{10}$$

$$\frac{\partial \mathcal{L}}{\partial C_r} = \lambda P_r, \tag{11}$$

$$\frac{\partial \mathcal{L}}{\partial C_m} = \lambda P_m. \tag{12}$$

Equations (9) and (10) show that at the optimum, households allocate labor for each activity until the expected marginal benefit is equal to the marginal opportunity cost of household time (γ). This suggests that marginal benefit and cost are prime candidates to be determinants of fire prevention.

Slutsky equations help us understand the implications of the models. It is possible to divide the total effect of a slight change in marginal benefit of fire prevention into substitution and income effects:

$$\frac{\partial L_p}{\partial W_p} = \frac{\partial L_p}{\partial W_p} \Big|_{U=\bar{U}} + \frac{\partial L_p}{\partial Y} Q_g, \tag{13}$$

where W_p stands for the marginal benefit of labor allocation for fire prevention ($P_{gj} \frac{\partial Q_g}{\partial L_p}$). The first term on the right-hand side of Equation (13) is a

substitution effect; the second term is an income effect. The substitution effect must be positive because a higher marginal value of prevention would increase net benefit of rubber production. The sign of the income effect is ambiguous; it depends on the relationship between income and leisure time. Findings from empirical studies on agricultural production suggest that the substitution effect outweighs the income effect in developing countries; therefore, the total effect might be positive (Fisher, 2005; Shively, 2004). The effect of a slight change in the marginal benefit of off-farm work on the labor allocation for fire prevention can be described as follows:

$$\frac{\partial L_p}{\partial W_o} = \frac{\partial L_p}{\partial W_o} \Big|_{U=\bar{U}} + \frac{\partial L_p}{\partial Y}(Q_o), \quad (14)$$

where W_o is the marginal benefit of labor allocation for off-farm work ($P_o \frac{\partial Q_o}{\partial L_o}$). The substitution effect of the first term is non-positive, while the income effect of the second term is indeterminate. This is because the term $\partial L_p / \partial Y$ can be either positive or negative depending on the demand for off-farm work and leisure time. Findings from previous empirical studies suggest that the total effect might be negative, and that increasing off-farm wages decreases engagement in agricultural work in developing countries (Jolliffe, 2004; Shively and Fisher, 2004).³ With this point in mind, we empirically investigate the relationship between the marginal benefit of labor allocation

³Previous studies find that increasing off-farm wages decrease the deforestation ratio because they assume that off-farm work and agriculture are substitutional work and

for rubber production or off-farm work and labor allocation to fire prevention.

Economic incentives offered by policy intervention can play a similar role as a marginal increase in the value of rubber production. A certain economic incentive for fire prevention (ρ) offered by a policy (KFCP, for example) increases the a household's expected marginal benefit of allocating labor for fire prevention activities ($\lambda(P_{gj})\frac{\partial Q_g}{\partial L_p} + \rho(L_p)$). The KFCP project announced that 30 million US dollars had been funded to mitigate deforestation in 14 communities in Blocks A and E of Kapuas Regency, this comprises 120,000 hectares of heavily degraded peatland and forests. KFCP was designed to promote household forest conservation and fire prevention activities by providing economic incentives. The project design document of KFCP describes three categories for incentives: (1) input-based incentives, such as building dams, planting trees, growing nursery plants, and eliminating fire use on peat soils; (2) performance-based incentives, such as maintaining dams to keep water levels high, protecting forests from encroachment, and reducing the incidence and extent of fires; and (3) outcome-based incentives, such as payment for actual reduced GHG emissions (KFCP, 2009, p.24). When insufficient economic incentives have been provided, the impact of KFCP is zero: $\rho(L_p) = 0$. In our interview conducted from October to December in 2012,

that additional agriculture work increases the ratio of deforestation. This factor is not considered in this paper.

all households in Blocks A and E reported that they had not received any economic incentives from KFCP for fire prevention at their plots, while some of them reported that they had received incentives for preparing nurseries for reforestation or for planting on project plot. This suggests that input-based incentives is offered rather than performance-based or outcome-based incentives.

Non-economic factors might also affect household fire prevention decisions. The role of social capital has received a great deal of attention in the context of effective management of common property resources (Ostrom, 1990). Fire prevention by individual farmers has the characteristics of the private provision of public goods because it might reduce the risk of peatland fire on surrounding farmland. The existence of the mutual assistance custom *Gotong-royong* allows us to evaluate the impact of social capital on fire prevention. *Gotong-royong* is a traditional community involvement and cooperative agricultural activities. For example, farmers jointly clear grass and harvest rice with nearby family as labor exchange or cooperation (Bowen, 1986). It also involves a wide range of reciprocal activity, from providing labor for infrastructure construction to financial support. This tradition affects individuals to exhibit a normative behavior for community. We examine the effect of *Gotong-royong* on fire prevention by using a dummy variable of participation in this activity.

3 Data

We collected household data via face-to-face interviews in twenty-nine communities in Kapuas Regency, Central Kalimantan, Indonesia (Figure 1). The communities were selected to obtain a balance of ethnicities and degree of involvement in the KFCP project. The communities consisted of 11 transmigrant and 18 Dayak tribe communities. Of the 18 Dayak communities, six were involved with the KFCP project. Table 1 summarizes the composition of the communities.⁴

In the interviews, respondents were asked about their economic status, type of agriculture, demographic characteristics, experience of fire damage, and fire prevention activities. Although we collected information from a total of 288 randomly selected households, in order to focus on the decisions of household heads, we excluded 73 responses by non-household heads and 35

⁴Two types of people have settled in Kapuas Regency: indigenous Dayak tribes that have traditionally lived there, and transmigrants that moved from other islands of Indonesia or other parts of Kalimantan (Fearnside, 1997). Transmigration to this area was promoted by government policy, especially during the Mega-Rice Project (MRP) in the 1990s. Although the government abandoned the MRP, a number of transmigrants continued to live in the area as rice farmers. Both communities rely on agricultural produce as their main source of income (De Jong et al., 2001).

responses with incomplete data.⁵ Thus, the final number of observations for the analysis was 182. Table 2 summarizes the descriptive statistics of the sample, which was divided into households that engage in fire prevention more than 60 days a year and those that do not, as well as those that were involved in the KFCP project and those that were not.

⁵For example, we left out respondents who do not engage in agriculture or who do not own any agricultural plots.

Table 1: Settlement composition

No.	Name of Village	Ethnicity		KFCP site
		Dayak	Transmigrant	
1.	Sei Ahas	✓		✓
2.	Katimpun	✓		✓
3.	Sei Kayu	✓		
4.	Mampai	✓		
5.	Sei Tatas	✓		
6.	Sei Pitung	✓		
7.	Sei Kayu	✓		
8.	Mandomai	✓		
9.	Mambulau	✓		
10.	Dahirang	✓		
11.	Sei Pasah	✓		
12.	Penda Katapi	✓		
13.	Lamunti A2		✓	
14.	Lamunti B1		✓	
15.	Lamunti B2		✓	
16.	Dadahup G3		✓	
17.	Dadahup G1		✓	
18.	Dadahup G2		✓	
19.	Dadahup A1		✓	
20.	Dadahup A6		✓	
21.	Dadahup A5		✓	
22.	Palingkau SP1		✓	
23.	Palingkau SP2		✓	
24.	Jangkang	✓		✓
25.	Kalumpang	✓		✓
26.	Tumbang Mangkup	✓		✓
27.	Tarantang	✓		
28.	Pulau Kaladan	✓		
29.	Mantangai Hulu	✓		✓

Table 2: Descriptive statistics for sample households

	Full sample		Households practicing fire prevention less than 60 days		Households practicing fire prevention more than 60 days		Households not involved with KFCP		Households involved with KFCP	
	$n = 180$		$n = 73$		$n = 107$		$n = 141$		$n = 39$	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Economic parameters</i>										
Shadow wage of rubber production (IDR/day/person)	10.65	7.09	7.60	7.76	12.72	5.76	9.41	7.55	15.12	0.35
Shadow wage of off-farm work (IDR/day/person)	8.68	6.45	10.48	5.67	7.45	6.69	8.95	6.32	7.70	6.90
Total size of agricultural plot (hectare)	3.45	4.81	2.63	3.23	4.01	5.58	2.90	3.39	5.46	7.83
Households with plots for rice production (0,1)	0.79	0.41	0.81	0.40	0.78	0.42	0.81	0.39	0.72	0.46
Size of rice plantation (hectare)	1.00	0.85	0.88	0.64	1.09	0.96	1.01	0.85	0.98	0.85
Cultivated rice product last year (kg)	928.11	1328.70	876.44	897.71	963.36	1559.10	1015.25	1439.96	613.08	739.62
Household with plots for rubber production (0,1)	0.58	0.50	0.45	0.50	0.66	0.47	0.50	0.50	0.87	0.34
Size of rubber plantation (hectare)	1.218	1.69	0.73	1.09	1.55	1.93	0.94	1.41	2.23	2.19
Cultivated rubber product last year (kg)	2291.71	5387.24	876.44	897.71	3284.67	6584.77	1280.76	2907.73	5946.67	9383.95
<i>Fire-related variables</i>										
Experienced fire damage in last five years (0,1)	0.38	0.49	0.32	0.47	0.43	0.50	0.32	0.47	0.62	0.49
Number of hot spots observed in 2012	2.89	6.91	1.23	1.91	4.03	8.66	3.21	7.60	1.74	3.23
Number of hot spots observed from 2008 to 2012	13.82	21.19	7.34	8.98	18.24	25.60	11.45	22.60	22.38	11.78
Number of hot spots observed from 2001 to 2007	30.32	38.91	24.92	38.63	34.00	38.84	26.35	40.83	44.67	26.83

Household characteristics

Involved with KFCP site (0,1)	0.22	0.41	0.18	0.39	0.24	0.43	-	-	-
Participate in <i>Gotong-royong</i> activities in last year (0,1)	0.64	0.48	0.49	0.50	0.74	0.44	0.66	0.48	0.56
Number of household members	4.38	1.69	4.19	1.33	4.50	1.89	4.19	1.46	5.05
Number of children (<6 years)	0.35	0.58	0.44	0.65	0.29	0.53	0.33	0.57	0.41
Access time to market (minutes)	59.46	70.75	61.95	75.92	57.77	67.31	38.35	31.01	135.77
Age of household head	46.76	10.95	46.16	11.20	47.16	10.80	47.48	10.91	44.13
Transmigrant (0,1)	0.46	0.50	0.51	0.50	0.42	0.50	0.55	0.50	0.13
Years on lot (year)	31.97	17.82	30.82	17.40	32.75	18.15	29.48	18.11	40.97
Engage in fire prevention in last year (0,1)	0.88	0.33	0.70	0.46	-	-	0.85	0.36	0.97
Days spent on fire prevention	129.42	153.18	23.32	21.95	201.81	162.02	126.55	152.28	139.82
Patrolling for fire prevention in last year (0,1)	0.78	0.42	0.52	0.50	0.95	0.21	0.75	0.43	0.87
Days spent for patrolling	51.17	79.97	11.03	15.20	78.56	93.68	41.80	58.62	85.05
Clearing grass for fire prevention in last year (0,1)	0.81	0.40	0.58	0.50	0.96	0.19	0.79	0.41	0.87
Days spend for clearing grasses	78.25	114.25	12.29	15.48	123.25	129.76	84.74	124.46	54.77
Engage in swidden agriculture in last year (0,1)	0.37	0.48	0.33	0.47	0.40	0.49	0.31	0.46	0.59
Size of burned plot for agriculture (hectare)	0.77	3.78	0.40	0.65	1.03	4.87	0.43	0.83	1.99
Allocate labor for off-farm work in last year (0,1)	0.65	0.48	0.78	0.42	0.56	0.50	0.67	0.47	0.56

Table 2 suggests that households in the area are faced with a high risk of fire damage. 38% of the households have experienced accidental fire damage on their agricultural plots. To reduce the risk of fire damage, 88% of the households have been engaging in fire prevention activities, either by patrolling (78%) or clearing grass (81%). We define a household as a fire prevention participator if it has engaged in patrolling or clearing grass at individual plots for fire prevention within the past 12 months prior to the interview.⁶ Households engaging in fire prevention more than 60 days a year tend to be exposed to a higher risk of fire damage. Experience of fire damage and the number of total hot spots nearby are higher for them than for others. Households living in areas where the KFCP project has been implemented seem more likely to engage in fire prevention than others. This may contain a reverse causality since the KFCP project has been implemented in areas where the risk of fire is higher. As a result, the number of hot spots in the KFCP project area is typically higher than places not involved with KFCP. To take this bias to our empirical estimation, we use instrumental variable methods. The dummy variable for the KFCP site is controlled by the number of hot spots from 2001 to 2007. Since KFCP began in 2008, the risk of fire from 2001 to 2007 might be suitable to control the endogeneity of policy

⁶The exact wording of the questionnaire is, “Do you clear grass on your land to prevent fires?” and “Do you look around your land carefully to prevent fires?”.

site choice.

The estimated mean shadow wage of rubber cultivation is IDR10.65 for the full sample.⁷ There are substantial differences in this figure between households that engage in fire prevention and those that do not. The estimated mean shadow wage of rubber cultivation for households that engage in fire prevention is IDR12.72, while that for households that do not engage in fire prevention is IDR7.60. The mean shadow wage of exogenous income is IDR7.45 for households engaging in fire prevention, and that for households not engaging in fire prevention is IDR10.48.

We define a household as a *Gotong-royong* participators if they have participated in any mutual activities, such as agricultural cooperation, constructing infrastructure, or maintaining public facilities for the community, in the 12 months prior to the interview. Table 2 suggests that *Gotong-royong*

⁷To define the opportunity cost of rubber production time, we estimated the production function. The F-statistic of the estimation is 38.17 with 127 degrees of freedom. The annual amount of rubber produced by households was used as the dependent variable. The independent variables that were statistically significant ($P > 0.01$) were household labor time (+), capital input (+), hired labor (+), chemical fertilizer input (+), years since the rubber was planted (+), and square of years since the rubber was planted (-). Chemical input and experience of fire damage were statistically insignificant. The estimated coefficient for the household labor time variable was used as the opportunity cost of rubber production time in the analysis of this section.

participators are more likely to engage in fire prevention than those not involved in *Gotong-royong* (74% and 49%).

4 Empirical Results

As Equation (9) suggests, households will not engage in fire prevention if the marginal benefit of fire prevention ($\lambda P_{gj} \frac{\partial Q_g}{\partial L_p}$) is less than the value of time (γ). This can be described as the corner solution of zero fire prevention, where $\lambda P_{gj} \frac{\partial Q_g}{\partial L_p} < \gamma \Leftrightarrow L_p = 0$. Since our sample contains households whose level of fire prevention is zero, we use a Poisson regression model and a Tobit model to consider the selection bias for estimation.

$$\ln(L_p) = \beta_0 + \beta_e X_e + \beta_s X_s + \beta_f X_f, \quad (15)$$

where X_e is a vector of explanatory variables of economic factors, X_s is a vector of explanatory variables of non-economic factors, such as household characteristics, decisions and KFCP intervention, and X_f is a vector of explanatory variables of the risk of fire damage such as experience of fire damage and the number of hot spots in 2012.⁸

⁸Hot spot data in our analysis cover the entire Kapuas Regency, from 114.000 to 114.450 degrees east longitude and from 2.05 to 3.40 degrees south latitude in the period from 2001 to 2012. We counted the number of hot spots on basis of 532 meshes that divided the

To evaluate the impact of KFCP, we must consider policy endogeneity since there is a possibility that households in the KFCP site are more likely to engage in fire prevention—not because of the project, but because of the higher risk of fire damage. To take this bias into account, we used the instrumental variable method. The instrument used in our analysis is the total number of hot spots observed by MODIS from 2001 to 2007. Since the project started in 2008, the hot spots from 2001 to 2007 can be considered as having an impact on KFCP site selection, but not on households fire prevention decision in 2012. Thus, we can mitigate the endogeneity caused by KFCP site selection. This is estimated with a IV-Tobit model.

Kapuas Regency with 0.05 degrees of longitude and 0.025 of latitude.

Table 3: Estimation models for either patrolling or clearing grass

Independent variable	Poisson		Tobit		IV-Tobit	
	Coefficient (Cluster S.E.)	Marginal effect	Coefficient (Cluster S.E.)	Marginal effect	Coefficient (Cluster S.E.)	Marginal effect
Household involved with KFCCP site	0.025(0.163)	0.045	0.061(0.360)	0.058	0.104(0.759)	0.100
Participate in <i>Golong-royong</i>	0.323(0.132)**	0.584***	0.660(0.263)**	0.638**	0.661(0.261)**	0.638**
Shadow wage of rubber products	0.029(0.012)**	0.052**	0.052(0.023)**	0.050**	0.052(0.024)**	0.050**
Shadow wage of off-farm work	-0.016(0.007)**	-0.028**	-0.034(0.014)**	-0.033**	-0.034(0.014)**	-0.033**
Amount of rice product cultivated last year	-0.015(0.012)	-0.027	-0.032(0.028)	-0.031	-0.032(0.029)	-0.031
Number of hot spots observed in 2012	0.048(0.062)	0.086	0.083(0.135)	0.080	0.086(0.159)	0.083
Experienced fire damage in last five years	0.006(0.097)	0.011	0.028(0.217)	0.027	0.020(0.260)	0.019
Number of household members	0.131(0.146)	0.236	0.311(0.332)	0.300	0.308(0.323)	0.297
Number of children age < 6	-0.172(0.145)	-0.311	-0.426(0.317)	-0.412	-0.422(0.335)	-0.407
Access time to market	-0.003(0.060)	-0.005	-0.017(0.134)	-0.017	-0.026(0.184)	-0.025
Age of household head	0.012(0.022)	0.021	0.027(0.052)	0.026	0.028(0.052)	0.027
Square age of household head	-0.000(0.000)	-0.000	-0.000(0.001)	-0.000	-0.000(0.001)	-0.000
Transmigrant	-0.218(0.191)	-0.394	-0.421(0.437)	-0.407	-0.402(0.522)	-0.388
Number of years on lot	-0.261(0.162)	-0.472*	-0.567(0.372)	-0.548	-0.563(0.375)	-0.544
Agriculture as primary source of income	0.318(0.171)*	0.574*	0.593(0.326)*	0.573*	0.595(0.330)*	0.575*
Size of agricultural plot	0.078(0.072)	0.142	0.174(0.159)	0.168	0.172(0.159)	0.166
The size of burned plot for agriculture	0.006(0.083)	0.011	0.086(0.185)	0.083	0.082(0.208)	0.079
Constant	0.411(0.759)		1.657(1.752)		1.656(1.758)	
Fitted test Prob > χ^2 (164)	0.997					
Pseudo R^2	0.125					
Log-likelihood	-266.593					
Akaike Information Criterion (AIC)	569.187					
Bayes Information Criterion (BIC)	626.859					
Number of observations	182					

***, **, and *==statistically significant at 1, 5, and 10%, respectively. Cluster standard errors are given in parentheses estimated coefficients. Variables except for dummies are in log form.

Table 4: Estimation models for patrolling

Independent variable	Poisson		Tobit		IV-Tobit	
	Coefficient (Cluster S.E.)	Marginal effect	Coefficient (Cluster S.E.)	Marginal effect	Coefficient (Cluster S.E.)	Marginal effect
Household involved with KFCP site	-0.112(0.232)	-0.141	-0.171(0.427)	-0.148	0.659(0.930)	0.565
Participate in <i>Golong-royong</i>	0.395(0.163)**	0.497***	0.583(0.244)**	0.504**	0.590(0.227)***	0.506***
Shadow wage of rubber products	0.039(0.017)**	0.049**	0.059(0.026)**	0.051**	0.051(0.028)*	0.044*
Shadow wage of off-farm work	-0.019(0.009)**	-0.024**	-0.034(0.015)**	-0.029**	-0.031(0.015)**	-0.027**
Amount of rice product cultivated last year	0.004(0.018)	0.005	0.019(0.036)	0.017	0.027(0.036)	0.023
Number of hot spots observed in 2012	0.126(0.083)	0.158	0.199(0.149)	0.172	0.259(0.181)	0.223
Experienced fire damage in last five years	0.098(0.131)	0.123	0.202(0.241)	0.175	0.058(0.276)	0.049
Number of household members	0.070(0.180)	0.088	0.121(0.316)	0.104	0.058(0.307)	0.050
Number of children age < 6	-0.183(0.192)	-0.230	-0.376(0.342)	-0.325	-0.292(0.373)	-0.250
Access time to market	0.020(0.073)	0.025	0.020(0.134)	0.017	-0.147(0.201)	-0.126
Age of household head	-0.033(0.023)	-0.041	-0.065(0.049)	-0.0561	-0.060(0.049)	-0.052
Square age of household head	0.000(0.000)	0.000	0.001(0.001)	0.000	0.001(0.001)	0.000
Transmigrant	0.005(0.244)	0.006	0.236(0.490)	0.204	0.624(0.733)	0.536
Number of years on lot	-0.055(0.224)	-0.070	-0.007(0.445)	-0.006	0.077(0.544)	0.066
Agriculture as primary source of income	0.410(0.207)**	0.516*	0.629(0.344)*	0.543*	0.670(0.355)*	0.575*
Size of agricultural plot	0.082(0.080)	0.103	0.178(0.150)	0.153	0.147(0.139)	0.126
The size of burned plot for agriculture	-0.073(0.125)	-0.092	0.004(0.199)	0.003	-0.071(0.212)	-0.061
Constant	0.036(0.899)		0.951(1.866)		0.898(2.005)	
Fitted test Prob > χ^2 (164)	0.897					
Pseudo R^2			0.112			
Log-likelihood	-241.391		-252.368		-241.321	
Akaike Information Criterion (AIC)	518.782		542.735		538.641	
Bayes Information Criterion (BIC)	576.454		603.612		628.354	
Number of observations	182		182		182	

***, **, and * = statistically significant at 1, 5, and 10%, respectively.
Cluster standard errors are given in parentheses with the estimated coefficients.
Variables except for dummies are in log form.

Table 5: Estimation models for clearing grasses

Independent variable	Poisson		Tobit		IV-Tobit	
	Coefficient (Cluster S.E.)	Marginal effect	Coefficient (Cluster S.E.)	Marginal effect	Coefficient (Cluster S.E.)	Marginal effect
Household involved with KFCP site	0.171(0.161)	0.190	0.246(0.292)	0.217	0.053(0.490)	0.047
Participate in <i>Golong-royong</i>	0.272(0.155)*	0.303*	0.440(0.228)*	0.388*	0.438(0.226)*	0.386*
Shadow wage of rubber products	0.027(0.012)**	0.030**	0.034(0.014)**	0.030**	0.036(0.015)**	0.031**
Shadow wage of off-farm work	-0.021(0.009)**	-0.023**	-0.033(0.012)**	-0.029**	-0.033(0.012)**	-0.029**
Amount of rice product cultivated last year	-0.040(0.016)**	-0.045**	-0.059(0.026)**	-0.052**	-0.060(0.026)**	-0.053**
Number of hot spots observed in 2012	-0.037(0.068)	-0.041	-0.069(0.098)	-0.060	-0.083(0.094)	-0.073
Experienced fire damage in last five years	-0.028(0.128)	-0.032	0.004(0.189)	0.004	0.038(0.219)	0.033
Number of household members	0.240(0.193)	0.266	0.397(0.311)	0.350	0.412(0.310)	0.363
Number of children age < 6	-0.355(0.210)*	-0.395*	-0.601(0.296)**	-0.530**	-0.621(0.292)**	-0.547**
Access time to market	-0.038(0.067)	-0.042	-0.061(0.108)	-0.054	-0.023(0.165)	-0.020
Age of household head	0.074(0.030)**	0.083**	0.106(0.045)**	0.094**	0.105(0.047)**	0.093**
Square age of household head	-0.001(0.000)**	-0.001**	-0.001(0.000)**	-0.001**	-0.001(0.000)**	-0.001**
Transmigrant	-0.838(0.264)**	-0.932**	-1.225(0.400)**	-1.079**	-1.312(0.348)**	-1.156**
Number of years on lot	-0.725(0.234)**	-0.805**	-1.069(0.388)**	-0.942**	-1.086(0.356)**	-0.957**
Agriculture as primary source of income	0.226(0.228)	0.251	0.233(0.297)	0.206	0.226(0.301)	0.199
Total size of agricultural plot	0.002(0.115)	0.003	-0.017(0.181)	-0.015	-0.009(0.183)	-0.008
Size of burned plot for agriculture	0.155(0.097)	0.172*	0.292(0.147)**	0.257**	0.309(0.155)**	0.272**
Constant	0.507(1.033)		1.952(1.628)		1.955(1.582)	
Fitted test Prob > χ^2 (164)	0.990					
Pseudo R^2	0.121					
Log-likelihood	-224.340					
Akaike Information Criterion (AIC)	484.681					
Bayes Information Criterion (BIC)	542.353					
Number of observations	182					

** *, **, and * = statistically significant at 1, 5, and 10%, respectively.
Cluster standard errors are given in parentheses with the estimated coefficients.
Variables except for dummies are in log form.

The estimation results for each category of prevention activity, patrolling and clearing grass, and both, are summarized in Table 3, Table 4 and Table 5, which show the respective specifications. The first specification (Column 1) uses a Poisson estimation and the second specification (Column 2) uses a Tobit model to take the sample selection biases into account. The third specification (Column 3) uses the instrumental variable method for the Tobit model. Table 6 shows the results of the first-stage regression for IV-Tobit models.

We found that the coefficients of KFCP are statistically insignificant in all estimations, indicating that the impact of KFCP is not enough to cause households to allocate additional time for fire prevention. This might be because KFCP has not offered payments for fire prevention on individual plots. Instead of offering performance-based or outcome-based incentives, most of KFCP project have focused on input-based incentives. For example, households reported that KFCP has rewarded them for preparing nurseries for reforestation or for planting on project plots. Such rewards can constitute an increase in households' exogenous income, which may create negative incentive for fire prevention activity. By increasing households' exogenous income, KFCP can deprive households of incentives to allocate labor for fire prevention at their own plots. As the coefficient of the shadow wage of off-farm work is negative and statistically significant, this might be plausi-

Table 6: KFCP site selection, first stage regression

Independent variable	Probit	IV
	Coefficient (Robust S.E.)	Coefficient (Robust S.E.)
Number of hot spots observed from 2001 to 2007	2.426*** (0.354)	0.139*** (0.038)
Participate in <i>Gotong-royong</i>	-0.398 (0.813)	-0.040 (0.065)
Shadow wage of rubber products	0.287*** (0.069)	0.008* (0.004)
Shadow wage of off-farm work	0.071* (0.041)	0.004 (0.003)
Amount of rice product cultivated last year	-0.047 (0.078)	-0.013 (0.008)
Number of hot spots observed in 2012	-1.007** (0.469)	-0.110** (0.048)
Experienced fire damage in last five year	2.504*** (0.443)	0.160*** (0.051)
Number of household members	1.221** (0.488)	-0.016 (0.052)
Number of children age < 6	-1.678*** (0.346)	-0.052 (0.044)
Access time to market	2.479*** (0.372)	0.189*** (0.042)
Age of household head	-0.220*** (0.079)	-0.009 (0.010)
Square age of household head	0.002*** (0.001)	0.000 (0.000)
Transmigrant	-4.502*** (0.612)	-0.429** (0.167)
Number of years on lot	-1.139** (0.473)	-0.019 (0.142)
Agriculture as primary source of income	-0.695 (0.734)	-0.099* (0.060)
Total size of agricultural plot	-0.406 (0.361)	0.017 (0.042)
Size of burned plot for agriculture	1.880*** (0.646)	0.104* (0.057)
Constant	-12.566*** (3.703)	-0.306 (0.518)
Number of observations	182	182
Pseudo R ²	0.853	

ble. Furthermore, KFCP might be insufficient in providing information and knowledge on its strategies. Resosudarmo et al. (2012) compared the knowledge of villagers between several REDD pilot projects and found that KFCP is relatively less acknowledged by local residents.

The estimation results suggest that in general, economic factors have a significant effect on decision making for fire prevention. The coefficient of the shadow wage of rubber production is positive and statistically significant at the 5% level at least in most of the estimations, indicating that households with higher values of rubber work are more likely to allocate labor for fire prevention. A higher rubber product value creates an incentive for households to protect themselves from fire damage. This result is consistent with Bowman et al. (2008), who found that the shadow wage of agricultural work has positive and statistically significant effect on household decision making on fire prevention. The coefficients of the shadow wage of off-farm work are negative and statistically significant, indicating that an increasing off-farm wage increases the opportunity cost of time (γ), and a high opportunity cost leads households not to allocate their time for fire prevention. These results mean that agricultural work and off-farm work are substitutes for households in this area and the substitution effect outweighs the income effect. The total effect of Equation (14) is positive and that of Equation (15) is negative.

The coefficients of *Gotong-royong* are positive and statistically significant

in most of the estimation, indicating that the households that participate in *Gotong-royong* are more likely to engage in fire prevention. Since *Gotong-royong* reinforces community's norms and ethics, it leads households to cooperate with each other. Another possibility is that *Gotong-royong* plays the role of a mutual surveillance system, allowing farmers to know what their neighbor are doing at their agricultural plots. This can function as peer pressure for more extensive fire prevention.

The coefficients of the experience of fire damage and the number of hot spots in 2012 are positive but statistically insignificant in the estimations. These results suggest that prevention activities by households might be based on subjective risk perception. Empirical findings show that households in developing countries are typically defined as risk-averse (Rosenzweig and Binswanger, 1993; Morduch, 1995; Barrett 1999; Shively, 2001).

5 Conclusions

This study estimated household labor allocation models by combining household survey data and satellite information for Kapuas Regency, Central Kalimantan, Indonesia. On the basis of the results, we can conclude that peatland fire prevention can be promoted by economic and non-economic incentives. This suggests that the REDD intervention incentive scheme would be able

to mitigate the risk of peatland fire as long as the design of the incentives is appropriate.

The effect of KFCP was not found to be statistically significant in our results. While KFCP was expected to be an ideal model to mitigate the risk of peatland fire, we found that it has no impact on household fire prevention decisions. This can be attributed to the fact that KFCP failed to develop an appropriate incentive scheme. For example, KFCP pays households planting or preparing trees for reforestation projects, but not for fire prevention. Increasing this kind of payment might decrease the amount of labor allocation for fire prevention since increasing the attractiveness of off-farm work would deprive households of their willingness to allocate labor for fire prevention.

Economic factors play a significant role in policy implementation. Increasing the productivity of rubber (the shadow wage of rubber production) would be an incentive for households to increase their labor share of fire prevention activity; however, increasing exogenous income may deprive households of their willingness to engage in fire prevention.

Non-economic factors are also important for effective policy implementation. Mutual assistance customs such as *Gotong-royong* might enhance the relationships between and the responsibility of households in the community. Thus, households that participate in *Gotong-royong* activities tend to allocate more labor and time for fire prevention at individual plots. Together,

these findings provide policy implications for the mitigation of forest fire and deforestation in Central Kalimantan as well as in other tropical regions. The high cost of implementing incentive schemes and the difficulty in monitoring individual actions are at the center of the international discussion on REDD as measurement, reporting and verification (MRV) problem. Policy design should include mutual pressure from each household and appropriate economic incentives to secure implementation.

References

- [1] Barrett, C. B. (1999) Stochastic food prices and slash-and-burn agriculture. *Environment and Development Economics* 4 (2):161-176
- [2] Van Beukering, P., Schaafsma, M., Davies, O., and Oskolokaite I. (2008) The economic value of peatland resources within the Central Kalimantan Peatland Project in Indonesia. Institute for Environmental Studies
- [3] Bowen, J. (1986). On the political construction of tradition: Gotong royong in Indonesia. *The Journal of Asian Studies*, 45(3), 545-561.
- [4] Bowman, M. S., Amacher G. S., and Merry F. D. (2008) Fire use and prevention by traditional households in the Brazilian Amazon. *Ecological Economics* 67 (1):117-130

- [5] Carlson, K. M. (2009) REDD pilot project scenarios: Are costs and benefits altered by spatial scale? *Environmental Research Letters* 4:1-3.
- [6] De Jong, W., Van Noordwijk, M., Sirait, M., Liswanti, N., and Suyanto (2001). Farming secondary forests in Indonesia. *Journal of Tropical Forest Science* 13:705-726.
- [7] Deveny, A., Nackoney J., and Purvis, N. (2009) *Forest Carbon Index: The geography of forests in climate change solutions. Resources for the Future.*
- [8] Fearnside, P. M. (1997) Transmigration in Indonesia: Lessons from its environmental and social impacts. *Environmental Management* 21 (4):553-570
- [9] Feigenberg, B., Field, E. M., and Pande, R. (2010) Building social capital through microfinance, NBER Working Papers 16018, National Bureau of Economic Research, Inc.
- [10] Fisher, M., Shively, G.E., and Buccola, S. (2005) Activity choice, labor allocation, and forest use in Malawi. *Land Economics* 81 (4):503-517
- [11] IPCC (2006) IPCC guidelines for national greenhouse gas inventories. In: Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (eds)

Prepared by the National Greenhouse Gas Inventories Programme. Institute for Global Environmental Strategies, Japan

- [12] Jolliffe, D. (2004) The impact of education in rural Ghana: Examining household labor allocation and return on and off the farm. *Journal of Development Economics* 73:287-314
- [13] KFCP (2009) Kalimantan Forests and Climate Partnership (KFCP) Design Document
- [14] Morduch, J. (1995) Income smoothing and consumption smoothing. *Journal of Economic Perspectives* 9 (3):103-114
- [15] Myers Madeira, E. C. (2008) Policies to reduce emissions from deforestation and degradation (REDD) in tropical forests: An examination of the issues facing the incorporation of REDD into market-based climate policies. *Resources for the Future*, December 2008.
- [16] Olbrei, E. and Howes, S. (2012) A very real and practical contribution? Lessons from the Kalimantan Forests and Climate Partnership. Development Policy Centre, Crawford School of Economics and Government ANU College of Asia and the Pacific, Australian National University
- [17] Ostrom, E., (1990) *Governing the commons: The evolution of institutions for collective action*, Cambridge, Cambridge University Press.

- [18] Page, S. E., Rieley, J. O., Shotyk, O. W., and Weiss, D. (1999) Interdependence of peat and vegetation in a tropical peat swamp forest. *Philosophical Transactions of the Royal Society*. 354:1885-1897.
- [19] Page, S. E., Siegert, F., Rieley, J. O., Boehm, H.-D. V., Jaya, A., and Limin, S. (2002) The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature* Vol. 420:61-65
- [20] Resosudarmo, I. A. D., Duchelle, A. E., Ekaputri, A. D., and Sunderlin, W. D. (2012) Local hopes and worries about REDD+ projects. in Angelsen, A., Brockhaus, M., Sunderlin, W. D., and Verchot, L. V. eds. *Analysing REDD+: Challenges and choices*. CIFOR.
- [21] Rosenzweig, M. R. and Binswanger, H. R. (1993) Wealth, weather risk and the composition and profitability of agricultural investments. *Economic Journal* 103 (416):56-78.
- [22] Shively, G. E., and Fisher M. (2004) Smallholder labor and deforestation: A systems approach. *American Journal of Agriculture Economics* 86, No.5:1361-1366.
- [23] Shively, G.E. (2001) Poverty, consumption risk, and soil conservation. *Journal of Development Economics* 65:267-290.

- [24] Sujarwoto S. and Gindo, T. (2013) Mother's social capital and child health in Indonesia. *Social Science and Medicine* 91:1-9.
- [25] Wibisana, W., Trihono, T., and Nurwati, S. (1999). *Community participation in health development: Indonesian experience*. Jakarta: Indonesia Ministry of Health.
- [26] Yamamoto, Y. and Takeuchi, K. (2012) Estimating the break-even price for forest protection in Central Kalimantan. *Environmental Economics and Policy Studies* 14(3):289-301.