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RESEARCH ARTICLE



Heterogeneous impacts of community forestry on forest conservation and poverty alleviation: Evidence from Indonesia

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Abstract

1. Community forestry is a participatory approach aiming to achieve sustainable forest management while also reducing poverty among rural communities. Yet, evidence of the impacts of community forestry programmes on both forest conservation and poverty alleviation is scarce, and there is limited understanding of impacts across different social and biophysical contexts.
2. We applied a matching method to assess the extent to which deforestation has decreased and village well-being has improved as a result of Indonesia's community forestry scheme, *Hutan Desa* (Village Forest). We assessed five dimensions of well-being: basic (living conditions), physical (access to health and education), financial (income support), social (security and equity) and environmental (natural hazard prevention).
3. We found that *Hutan Desa* was associated with reduced deforestation and poverty. 'Win-win' outcomes were found in 51% of cases, comprising (a) positive outcomes for both forests and poverty, (b) a positive outcome for one aspect and a negligible outcome for the other, or (c) a positive outcome for poverty in areas where natural forest had already been lacking prior to *Hutan Desa* tenure. Benefits to forests and people systematically differed depending on land-use zones, reflecting subtle interactions between anthropogenic pressures and community livelihood characteristics.
4. In Watershed Protection Zones, which are dominated by subsistence-based forest livelihoods, community forestry provided mild conservation benefits, but resulted in the greatest improvements in well-being through improved land tenure. In Limited Production Zones, community forestry provided modest benefits for

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both conservation and well-being because restrictions on timber harvest due to *Hutan Desa* designation reduced the financial well-being of logging communities. The greatest conservation benefits were experienced in Permanent or Convertible Production Zones, but well-being improvements were minimal. Here, living conditions and environmental well-being were reduced due to pressure to intensify agricultural production under increased land scarcity in these predominantly cash crop-oriented communities.

5. Our results highlight the spatial and contextual variation in impacts of community forestry policies on poverty alleviation and forest conservation outcomes. Crucially, our study provides vital objective information for future policy development in Indonesia and other tropical countries implementing community forestry schemes.

KEYWORDS

avoided deforestation, human well-being, impact evaluation, multidimensional poverty, rural development, sustainable development, tropics

1 | INTRODUCTION

The developing world is experiencing unprecedented degradation of the natural environment (Hoekstra & Wiedmann, 2014). While economic growth has lifted millions of people out of poverty, rural deprivation remains prevalent (Akram-Lodhi, Borrás, & Kay, 2007). In recognition of the dual objectives of reducing poverty and improving ecosystem conservation, developing country governments and international donors are promoting policies that involve communities in environmental management, such as community forestry (CF; Bowler, Buyung-Ali, Healey, Jones, & Knight, 2012; Sayer & Margules, 2017). The Indonesian government adopted CF in 2014, setting an ambitious target of 10% of the country's forests (12.7 Mha) allocated to this purpose by 2019 (National Medium-Term Development Plan (RPJMN) 2015–2019), of which *ca.* 2.3 Mha has already been assigned (MEF, 2018b). The principle aims of CF in Indonesia are to help alleviate poverty among rural communities, while also avoiding deforestation. This shift in land tenure is unprecedented in Indonesia, and is one of the largest CF policies of any tropical country (Meijaard, Budiharta, & Santika, 2017). Around one-third of the proposed CF area is in the tropical forests of Kalimantan, Indonesian Borneo (MEF, 2018a). With much more land set to be allocated to CF, it is timely to evaluate whether Indonesia's policy as currently interpreted is fulfilling its main conservation and social objectives.

Empirical evaluations of CF have often focused on a single perspective; either the conservation outcome (e.g. Luintel, Bluffstone, & Scheller, 2018; Rasolofson, Ferraro, Jenkins, & Jones, 2015; Santika et al., 2017), or well-being (e.g. Rahut, Ali, & Behera, 2015; Rasolofson et al., 2017). Evaluations that combine socioeconomic

development with environmental conservation outcomes are imperative to understand potential trade-offs or synergies between the two potential impacts, and how these vary across different social and landscape contexts (Agrawal & Chhatre, 2006). Nonetheless, many CF evaluations have focused on well-being aspects, and have typically done so via localized case studies using a limited subset of well-being measures (Bowler et al., 2012; Burivalova, Hua, Koh, Garcia, & Putz, 2017; Mongabay, 2017). For example, although there have been numerous studies examining CF programmes in Indonesia, these have focused mainly on financial outcomes and conflict (Table S1). Assessments that integrate both conservation and well-being perspectives are rare (Gilmour, 2016; Newton et al., 2015).

Despite the rich literature detailing institutional arrangements for CF, there are few studies that examine the role of socioeconomic, market and biophysical factors in shaping actual outcomes (Hajjar & Oldekop, 2018; Hajjar et al., 2016; Newton et al., 2015). There is therefore limited objective information with which to guide the development of policies, monitor performance, and scale up implementation. Deeper understanding of what influences performance would also allow CF policies to be better tailored for communities to enhance both social and environmental outcomes (Ostrom & Nagendra, 2006). At present, there is a risk that CF policies that fulfil environmental objectives could result in negative impacts on poverty, or vice versa; yet comprehensive baseline assessments that enable reliable monitoring and evaluation are often lacking.

For CF policy evaluation to be robust, any attribution of changes in forest cover or poverty due to the policy should be compared to the counterfactual condition of no CF or other confounding factors (Baylis et al., 2016; Lan & Yin, 2017). Policy instruments usually target certain populations with specific underlying characteristics,

thereby introducing selection bias when measuring performance and masking true outcomes. Matching techniques select controls with similar observed characteristics as the populations receiving the intervention, and thus can overcome such bias by providing a fair and reliable way of comparing sites with different intervention exposure (Dehejia & Wahba, 2002). Matching methods have been used widely in assessing the impact of protected areas (e.g. Ferraro & Hanauer, 2011) and certification of logging operations (e.g. Miteva, Loucks, & Pattanayak, 2015), but their use in CF evaluation is uncommon (e.g. Rasolofoson et al., 2015; Rasolofoson et al., 2017).

Here, we determine the extent to which CF in Indonesia has resulted in both reduced deforestation and improved well-being. Well-being is multidimensional, and incorporates economic, social and environmental perspectives (Alkire & Santos, 2014). The aspects of well-being examined include: (a) basic (living conditions), (b) physical (access to health and education), (c) financial (income support), (d) social (security and equity) and (e) environmental (natural hazard prevention). We focus our socio-ecological analysis on *Hutan Desa* or 'Village Forest', the main CF scheme being applied in Kalimantan and elsewhere in Indonesia. *Hutan Desa* aims to reduce poverty and improve the social welfare and forest use rights of marginalized communities by allowing forests to be protected and managed communally through the authority of a village head (Myers & Ardiansyah, 2014). *Hutan Desa* licences are granted by the Ministry of Environment and Forestry through a rigorous selection process, where the approval of the licence is based on the provision of a management plan with goals towards sustainable development and conservation, strong participation from the local community, and collaborative relationships with external partners, such as non-governmental organizations (Siscawati et al., 2017). We assessed: (a) the association between *Hutan Desa*, deforestation rates and the change in different aspects of village well-being; and (b) variation of these associations in different areas in Kalimantan. From our results, we provide recommendations to improve CF policy that reflect how performance varies in different contexts.

2 | MATERIALS AND METHODS

2.1 | Study area, land-use zones and unit of analysis

Kalimantan covers 530,000 km² within five provinces. Here, and elsewhere in Indonesia, *Hutan Desa* licenses are granted in different state forest zones: Watershed Protection Zone (where timber harvesting is prohibited); Limited Production Zone (where timber harvesting is permitted, but within quotas); or Permanent or Convertible Production Zone (where some forest clearing is permitted; Figure 1a). *Hutan Desa* has typically been granted outside active forest and agricultural concessions (i.e. logging concessions, timber or oil palm plantations). By 2018, 105 *Hutan Desa* licences (~376,000 ha) had been granted in Kalimantan, with 58% assigned in Watershed Protection Zone, 18% in Limited Production Zone and 24% in Permanent or Convertible Production Zone (MEF, 2018a).

Our assessment included 41 *Hutan Desa* management areas (total 1,300 km²) that had been approved and facilitated by external organizations between 2009 and 2014, the latest period corresponding to sufficient forest cover and well-being data. The spatial unit of the analysis was 1 × 1 km² grid-cell resolution for the deforestation outcome, and village boundaries for well-being. We assessed the performance of *Hutan Desa* for each land-use zone, because regulation on the amount of timber extraction permitted within *Hutan Desa* boundaries differs by zone. Timber extraction is prohibited in *Hutan Desa* granted in Watershed Protection Zone, but in Production Zones (including Limited Production Zone and Permanent or Convertible Production Zone) timber extraction is permitted up to 50 m³ per *Hutan Desa* management area per year for non-commercial use as long as this does not result in net deforestation (Ministerial Decree No. P. 89/2014 Article 33).

Livelihoods in Kalimantan are primarily subsistence-based (swidden farming, fishing and forest product collection in complex agroforestry landscapes), plantations (polyculture plantations of rubber, oil palm, coffee, and/or coconut, or monoculture plantations of oil palm) and other sectors (including horticulture, aquaculture, livestock, and coastal fishery; BPS Indonesia, 2017). Large-scale logging and oil palm concessions are also widespread (Gaveau, Salim, & Arjasakusuma, 2016; Santika, Meijaard, & Wilson, 2015). Combining information on livelihoods and concession types provides more nuanced information on livelihood sectors across Kalimantan's villages: (a) subsistence livelihoods outside any concessions, (b) subsistence livelihoods within logging concessions, (c) plantations outside any concessions (mainly polyculture plantation smallholders), (d) plantations within oil palm concessions (mainly large company plantations and smallholders operating as part of the nucleus estate system with cooperation between company plantations and smallholders in terms of capital and labour supply) and (e) other sectors (Figure 1b).

In the Watershed Protection Zone, most communities rely on subsistence livelihoods outside concessions (livelihood category 1), whereas in the Limited Production Zone, subsistence livelihoods within logging concessions (livelihood category 2) are the norm (Figure 1c). The indigenous Dayak also tend to comprise more of the population in the Watershed Protection Zone and Limited Production Zone than in Permanent or Convertible Production Zones (Figure S1). In the Permanent or Convertible Production Zones, plantations, both outside and within oil-palm concessions (livelihood categories 3 and 4), dominate (Figure 1c), and the proportion of non-indigenous people, including migrants from Java and Sumatra, is also relatively high (Figure S1).

2.2 | Data on well-being

Indicators of well-being were derived from *Potensi Desa* (PODES; 'Village Potential') data from the Indonesian government. PODES is a publicly available village-level socioeconomic dataset collected every 2–4 years by the Bureau of Statistics Indonesia (BPS Indonesia, 2017). The data represent the overall socioeconomic conditions in a village, and thus do not capture the variation and

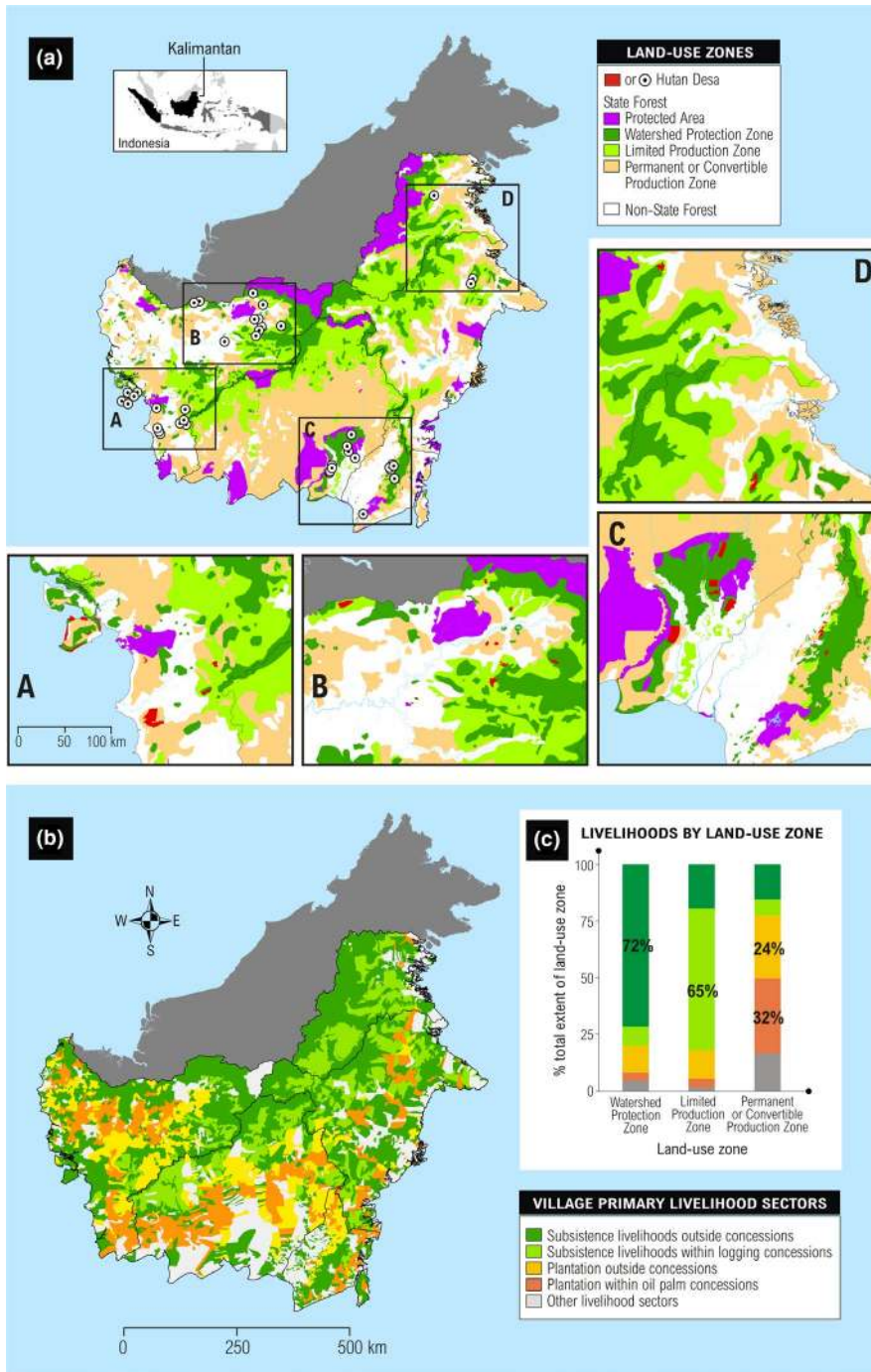


FIGURE 1 The distribution of *Hutan Desa* and land-use zones across Kalimantan by February 2015 (a); village primary livelihoods sectors (b); and the break down of livelihoods according to zone (c). Black lines in the maps indicate provincial and national boundaries

disparity in socioeconomic indicators among different sub-villages or households. Rather, the data provide a useful way to compare village administrative units over large spatial extents and over time.

PODES data are collected from village head offices. The reliability of data, therefore, may vary across different villages, resulting in potential for bias. However, should this bias propagate sufficiently to affect the outcome of analysis, then we would expect it to override the signal of CF (i.e. no impact of *Hutan Desa* would be observed), as opposed to overstating (or understating) the impact. PODES is the best socioeconomic dataset available at sufficient spatial resolution in Indonesia. The data have been used extensively in rural

development studies (Table S2) and have proven useful for monitoring the various socioeconomic impacts of land-use policy interventions (e.g. Barron, Kaiser, & Pradhan, 2009; Jagger & Rana, 2017; Miteva et al., 2015).

We used 16 indicators derived from PODES 2008 and 2014 collections as proxies for the change in five aspects of well-being (Table 1). The choice of indicators and directionality of the effects on well-being was informed by existing methodologies used to assess poverty, such as the Multidimensional Poverty Index (Alkire & Santos, 2014), the Sustainable Livelihood Approach (Scoones, 1998), and the Nested Spheres of Poverty tool (Gönnér, Haug, Cahyat, Wollenberg,

TABLE 1 *Potensi Desa* (PODES) variables used as proxies for five aspects of well-being: basic, physical, financial, social and environmental. w_k denotes the directional effect of the change in indicator k that defines improvement in well-being. If $w_k = 1$, then positive change (i.e. an increase) in indicator k represents improvement in well-being. If $w_k = -1$, then negative change (or reduction) in indicator k represents improvement in well-being

Aspect of well-being	PODES variable (k)	Variable response	Directional effect of the change in variable k that defines improvement	
			w_k	Meaning
Basic (living conditions)	Proportion of households with poor housing conditions ^c	Continuous	-1	Well-being improves when fewer households have poor housing conditions
	Proportion of households with electricity ^c	Continuous	1	Well-being improves when more households have electricity
	Incidents of child malnutrition in the last year ^a	Continuous	-1	Well-being improves when there are fewer malnutrition incidents
Physical (access to health and education)	Cooking fuel for majority of households	Categorical (1 = liquefied petroleum gas (LPG) or electricity, 2 = kerosene, 3 = wood/others)	-1	Well-being improves when there is change to lower fuel, e.g. a change from category 3 (wood/others) to 2 (kerosene)
	Toilet facilities for majority of households	Categorical (1 = own toilet, 2 = joint toilet, 3 = public toilet, 4 = non-toilet)	-1	Well-being improves when there is change to a lower category, e.g. a change from category 2 (joint toilet) to 1 (own toilet)
	Distance to nearest health facility	Continuous	-1	Well-being improves when health facilities are nearby.
Financial (income support)	Distance to nearest primary school	Continuous	-1	Well-being improves when primary schools are nearby
	Distance to nearest secondary school	Continuous	-1	Well-being improves when secondary schools are nearby
	Number of active village cooperative schemes or other related schemes ^b	Continuous	1	Well-being improves when active cooperative schemes or other related schemes are more prevalent
Social (security and equity)	Number of credit schemes received by farmers or communities in the last year ^b	Continuous	1	Well-being improves when there are more credits available for farmers or communities
	Number of small enterprises (<20 employees) ^b	Continuous	1	Well-being improves when small enterprises are more prevalent.
	Frequency of conflicts among communities in the last year	Continuous	-1	Well-being improves when conflicts are less prevalent
Environmental (natural hazard prevention)	Proportion of families with agricultural wage labourers ^d	Continuous	-1	Well-being improves when families with agricultural wage labourers are less prevalent
	Frequency of floods and landslides in the last three years	Continuous	-1	Well-being improves when floods and landslides are less frequent.
	Water pollution in the last year	Categorical (1 = none, 2 = mild, 3 = severe)	-1	Well-being improves when there is a change to a lower water pollution category, e.g. a change from category 2 (mild) to 1 (none)
	Air pollution in the last year	Categorical (1 = none, 2 = mild, 3 = severe)	-1	Well-being improves when there is change to lower air pollution category, e.g. a change from category 2 (mild) to 1 (none)

^aPer 1,000 people.

^bPer 100 households.

^cOf total households.

^dOf total agriculture families.

& Jong, 2007; Figure S2). Further details on indicators and justification for their directionality are provided in Supplementary Materials and Table S3. We recognize that more subjective, non-material, indicators exist to measure poverty and human well-being (Biedenweg et al., 2014; Breslow et al., 2016; Chan, Satterfield, & Goldstein, 2012). However, these are difficult to aggregate at the village level and are not available within the PODES dataset. Our analyses should therefore be interpreted as documenting changes in objective, material aspects of well-being.

2.3 | Data on deforestation

We used deforestation rate as an indicator of forest conservation. We assessed the impact of *Hutan Desa* on deforestation rates based on data between 2010 and 2014 to roughly match the time period covered by the PODES data. Deforestation rates were derived from the forest loss variable in the Global Forest Change (GFC) dataset (Hansen et al., 2013). The GFC dataset does not distinguish between the loss of natural forest and that of tree plantations. Therefore, to restrict our analysis to natural forest loss, we used the extent of natural forest in 2010 derived from Margono, Potapov, Turubanova, Stolle, and Hansen (2014). Natural forest is defined as a mature forest that has not been completely cleared in the last 30 years. The GFC dataset was then restricted to the extent of natural forest in 2010. The GFC and natural forest extent data both have spatial resolution $30 \times 30 \text{ m}^2$, and we analysed forest cover change annually in hectares at a spatial resolution of $1 \times 1 \text{ km}^2$. We focused on deforestation of intact natural forest, that is, $1 \times 1 \text{ km}^2$ grid-cells with >80 hectares of natural forest in the beginning of *Hutan Desa* tenure. Among the 41 *Hutan Desa* areas we examined, 32 were mostly (>70%) covered by natural forest in 2010, and were included in our deforestation assessment. Because interannual climate variation between 2010 and 2014 was within the normal range (mostly categorized as non-dry years, Figure S3), we assumed that deforestation was largely driven by anthropogenic activities during this period, rather than drought-induced fire.

2.4 | Confounding variables

We controlled for potentially confounding variables in the assessment of *Hutan Desa* performance in terms of which locations were selected for *Hutan Desa* and the outcome being measured (Table 2). These included variables representing: (a) *Hutan Desa* assignment, (b) sociopolitical factors, (c) accessibility or market value and (d) agricultural productivity.

Licenses for *Hutan Desa* are granted in state forest land in different land-use zones. To control for this, we determined the dominant legalized land-use zone (variable *LZONE*) of each parcel. We used provincial boundaries (variable *PROV*), the presence of a non-governmental organization (NGO) partnership (variable *NGO*), primary livelihood of communities (variable *LVHD*), and indicator of well-being prior to *Hutan Desa* designation in 2008 (variable *WLB*) as proxies for sociopolitical factors. Decentralization of government

functions to provincial levels has been identified as a key driver of agriculture expansion (Moeliono & Limberg, 2012; Resosudarmo, 2004). Economic growth can also vary across different provinces (Suryahadi, Suryadarma, & Sumarto, 2009). NGO partnerships are pre-requisite to applying for a *Hutan Desa* license (Siscawati et al., 2017), and recognized as an important factor in improving the performance of community forestry (Akiefnawati et al., 2010). Therefore, the net impact of *Hutan Desa* tenure should account for the NGO influence in the deforestation and well-being outcome within *Hutan Desa* area. The indicator of well-being prior to *Hutan Desa* designation provides a baseline to control for initial conditions that may bias impact estimates.

We used elevation (variable *ELEV*), slope (variable *SLOPE*), proximity to large cities or arterial roads (variable *CITY*) and human population density (variable *POP*) as proxies for market value. Communities living in areas closer to roads, at lower elevation and flat terrain, and in areas of higher human population density tend to have better socioeconomic welfare than those living in remote areas without exposure to the market economy (Resosudarmo & Jotzo, 2009; Sunderlin, Dewi, & Puntodewo, 2007).

We used long-term seasonal rainfall patterns (variables *DRY* and *WET*), location on peat soil (variable *PEAT*), baseline forest cover in 2008 (variable *FOR*), distance to oil palm plantations (variable *OPP*) and transmigration areas (variable *TRANS*), and monthly mean rainfall during the dry season (May to September) between 2008 and 2014 (variable *TDRY*) and the monthly mean rainfall during the wet season (November to March of the following year) within the same period (variable *TWET*) as proxies for agriculture productivity. The amount of rainfall during the dry and wet seasons is one among the more important factors affecting agricultural productivity in Indonesia (Oldeman & Frere, 1982), thus driving agriculture expansion and economic growth. Soil condition, such as type (peat or mineral soil) is also an important factor driving agricultural conversion (Carlson et al., 2013). The decline in forest area in Kalimantan had been partly attributed to an increase in agricultural area, much of which is linked to transmigration sites (Dennis & Colfer, 2006). Extreme climate, such as prolonged dry months and heavy rains, can decrease agriculture productivity (Iizumi & Ramankutty, 2015; Oettli, Behera, & Yamagata, 2018) and increase natural disasters such as wildfire and flood (Field, Werf, & Shen, 2009). Such extreme events can lead to reduced economic growth and adversely affect community social welfare (Herawati & Santoso, 2011).

2.5 | Matching method

We employed propensity score matching (Rosenbaum & Rubin, 1983) to select a set of control grid-cells outside *Hutan Desa* boundaries that exhibited the same baseline characteristics as grid-cells with *Hutan Desa*. We used a nonparametric generalized boosted regression model implemented in the R-package *gbm* (Ridgeway & Southworth, 2015) to generate the propensity scores using the variables described in Table 2. After generating the propensity scores, the *Hutan Desa* locations were

TABLE 2 Confounding variables controlled for in the assessment of the impacts of *Hutan Desa* on deforestation and well-being

Variable	Description	Type (scale/response)	Data source
<i>Hutan Desa</i> assignment			
LZONE	Legalized land-use zone	Categorical (HL = Watershed Protection Zone, HPT = Limited Production Zone, HPTK = Permanent or Convertible Production Zone)	MEF (2016a)
Sociopolitical			
PROV	Provincial boundaries	Categorical (W = West, S = South, C = Central, E = East, and N = North Kalimantan province)	Provincial Map (BIG, 2015)
NGO	NGO involvement	Categorical (1 = Yes, 0 = No)	PIAPS (MEF, 2018a)
LVHD	Village primary livelihood (Figure 1b)	Categorical (1 = subsistence livelihoods outside concessions, 2 = subsistence livelihoods within logging concessions, 3 = plantations outside concessions, 4 = plantations within oil-palm concessions, and 5 = other sectors)	<i>Potensi Desa</i> (PODES) data (BPS Indonesia, 2017) for livelihood, MEF (2016b) and Santika et al. (2015) for logging concessions, timber plantation concessions, and oil palm concessions
WLB _k	Baseline well-being indicator k in 2008 (Table 1)	Either continuous or categorical	<i>Potensi Desa</i> (PODES) data (BPS Indonesia, 2017)
Market value			
ELEV	Altitude	Continuous (log(m))	SRTM 90m Digital Elevation Database v4.1 (Jarvis, Reuter, Nelson, & Guevara, 2008)
SLOPE	Slope	Continuous (log(degree))	SRTM 90m Digital Elevation Database v4.1 (Jarvis et al., 2008)
CITY	Distance to large cities or arterial roads	Continuous (log(km))	Provincial Map (BIG, 2015)
POP	Human population density	Continuous (log(people))	<i>Potensi Desa</i> (PODES) data (BPS Indonesia, 2017)
Agricultural productivity			
DRY	Long-term monthly rainfall during dry season	Continuous (mm)	WorldClim (Fick & Hijmans, 2017)
WET	Long-term monthly rainfall during wet season	Continuous (mm)	WorldClim (Fick & Hijmans, 2017)
PEAT	Majority of soil type	Categorical (1 = Peat, 0 = Mineral)	MEF (2016b)
FOR	Forest cover in 2008	Continuous (ha)	Hansen et al. (2013); Margono et al. (2014)
OPP	Distance to oil-palm plantations	Continuous (log(km))	MEF (2016b); Gaveau et al. (2016)
TRANS	Distance to transmigration areas	Continuous (log(km))	MEF (2016b)
TDRY	Monthly rainfall during the dry season between 2008 and 2014	TRMM Multi-Satellite Precipitation Analysis (TMPA) v. 7 (Huffman et al., 2007)	
	Continuous (mm)	TRMM Multi-Satellite Precipitation Analysis (TMPA) v. 7 (Huffman et al., 2007)	
TWET	Monthly rainfall during the wet season between 2008 and 2014	Continuous (mm)	

matched with locations without *Hutan Desa* status using the nearest neighbour approach (with calliper widths 0.2 of the propensity score standard deviations) implemented in the R-package Matching (Sekhon, 2015). We ensured that the categorical baseline characteristics (i.e. variables *LZONE*, *NGO*, *PROV*, *PEAT*, *LVHD* and *WLB*) of the control locations exactly matched the characteristics of locations with *Hutan Desa*. The distribution of baseline continuous variables and well-being indicators between locations with and without *Hutan Desa* had a higher degree of overlap after matching than before matching (Figure S4 and Table S4).

After the matched dataset was obtained, we estimated the efficacy of *Hutan Desa* in reducing deforestation by comparing the annual deforestation rates in $1 \times 1 \text{ km}^2$ grid-cells within the boundaries of *Hutan Desa* (32 areas) with the rates in the control grid-cells. A grid-cell i with *Hutan Desa* management is considered to be effective at reducing deforestation if the difference between the deforestation rates in the treated grid-cell (R_i) and the control grid-cell (\hat{R}_i), that is, ρ_i , where $\rho_i = R_i - \hat{R}_i$ is negative. Averaging ρ_i across all grid-cells within each *Hutan Desa* management unit j resulted in an estimate of the performance of each *Hutan Desa* on deforestation, that is \bar{R}_j . If \bar{R}_j is considerably negative, considerably positive, or around zero, then the *Hutan Desa* management unit j has lower, higher, or similar deforestation rates than that outside the *Hutan Desa*, and the *Hutan Desa* management is likely to have a positive, negative, or negligible impact on avoiding deforestation.

To estimate the efficacy of *Hutan Desa* in improving well-being, we compared the change in each indicator between 2008 and 2014 (Table 1) in villages with *Hutan Desa* (41 areas) with the change in the control villages without it. A village j with *Hutan Desa* is considered to be effective at improving a single indicator of well-being k if the difference between the change in the value of indicator in the treated village ($C_{j,k}$) and the control village ($\hat{C}_{j,k}$), that is $\gamma_{j,k}$, where $\gamma_{j,k} = w_k \times (C_{j,k} - \hat{C}_{j,k})$, is positive. Averaging γ_j across all indicators of well-being k , then across all aspects of well-being m yielded an estimate of the performance of each *Hutan Desa* on well-being, that is, ζ_j . If ζ_j is considerably positive, considerably negative or around zero, then the change in well-being in villages with *Hutan Desa* j occurs faster, slower or at similar pace as that in villages without *Hutan Desa*, and the *Hutan Desa* management is likely to have a positive, negative or negligible impact on well-being.

To assess whether or not our estimate based on matching was robust to the possible presence of an unobserved confounder, a sensitivity analysis was applied based on the principle of randomization inference (Keele, 2014). The results indicated that if an omitted confounding variable does exist, it has to increase the likelihood of the non *Hutan Desa* village to receive intervention by a factor greater than at least 1.81 (Table S5). This magnitude suggests that our matching method is robust to hidden bias. Detailed explanations of the matching method are provided in the Supplementary Materials.

3 | RESULTS

3.1 | Association between *Hutan Desa* and avoided deforestation

Hutan Desa was associated with reduced deforestation rates overall compared to the counterfactual (Figure 2a). We detected deforestation in intact natural forest areas both inside and outside the boundaries of *Hutan Desa* with similar baseline biophysical conditions. However, deforestation rates inside *Hutan Desa* were lower overall than outside *Hutan Desa*.

The association between *Hutan Desa* and reduced deforestation varied across different land-use zones (Figure 2b). When established in Permanent or Convertible Production Zone, *Hutan Desa* had considerably higher levels of avoided deforestation relative to controls. Less avoided deforestation was observed in *Hutan Desa* established in Limited Production Zone and Watershed Protection Zone.

3.2 | Association between *Hutan Desa* and indicators of well-being

Compared to the counterfactual, *Hutan Desa* in Kalimantan was associated with overall improvements to well-being averaged over all indicators between 2008 and 2014 (Figure 2c). Both in villages with *Hutan Desa* and those without, we detected an increase in basic, physical and financial indicators of well-being, and decline in social and environmental measures. However, well-being improvements were more pronounced, on average, in villages where *Hutan Desa* had been established. Additionally, the overall decline in social and environmental well-being was lower in villages with *Hutan Desa* compared to villages without.

The association between *Hutan Desa* and well-being indicators also varied across different land-use zones (Figure 2d). Communities residing within Watershed Protection Zones exhibited greater improvements in all aspects of well-being than those in limited production zones, where financial well-being indicators declined over the study period (Figure 3a). Communities in permanent or convertible production zones also benefited in some aspects, but not in relation to our measures of basic and environmental well-being (Figure 3a), particularly if they were in peatlands (Figure S5).

The heterogeneous impacts of *Hutan Desa* on well-being across different land-use zones reflect dominant livelihood characteristics present. Impacts among communities with subsistence livelihoods outside concessions (Figure 3b) show similar patterns to the overall impact within Watershed Protection Zone (Figure 3a). Similarly, the impacts among communities with subsistence livelihoods within logging concessions (Figure 3b) show similar patterns to the overall impact within the Limited Production Zone (Figure 3a), and the impacts among communities living within plantations (both outside and within oil-palm concessions) (Figure 3b) show similar patterns to the overall impact within the Permanent or Convertible Production Zone (Figure 3a).

Of the indicators of basic well-being we assessed, access to electricity, clean cooking fuel, and adequate sanitations were considerably affected by the *Hutan Desa* designation (Figure S6a). *Hutan Desa* was typically associated with improvement of these indicators compared to the counterfactual in Watershed Protection Zone and Limited Production Zone, but not in Permanent or Convertible Production Zone. Among indicators of physical well-being assessed, access to secondary schools was affected considerably by *Hutan Desa* designation (Figure S6b), and improved access to secondary schools was prominent, particularly in Permanent or Convertible Production Zone. Among indicators of financial well-being assessed, improved access to credit was prominent in *Hutan Desa* granted in Watershed Protection Zone and Permanent or Convertible Production Zone, and the prevalence of small-scale enterprises was also enhanced considerably in Watershed Protection Zone (Figure S6c). Among indicators of social well-being, reduction in the prevalence of agricultural wage labourers was substantial in *Hutan Desa* granted in Permanent or Convertible Production Zone (Figure S6d). Among indicators of environmental well-being, air and water pollutions were significantly affected by the *Hutan Desa* designation (Figure S6e); air pollution reduced substantially in all land-use categories, but water pollution was exacerbated in Permanent or Convertible Production

Zone, the zone where larger proportion of *Hutan Desa* was granted on peatland.

4 | DISCUSSION

Our study provides the first broad jurisdictional assessment of the impacts of CF on forest conservation and rural well-being seen through a multidimensional lens. We found that Indonesia's main CF scheme, *Hutan Desa*, was associated with both reduced deforestation and improved indicators of well-being for Kalimantan's rural communities (Figure 4). Positive outcomes for both conservation and well-being, or a positive outcome for one aspect and negligible for the other, were detected in 51% of cases (sum of cells A in Figure 4), suggesting that, under some circumstance, forest conservation can go hand-in-hand with poverty alleviation. Negligible outcomes for both conservation and well-being were detected in 14% of cases (sum of cells B in Figure 4). Conversely, trade-offs between conservation and well-being were detected in 17% of cases (sum of cells C in Figure 4); with 13% of cases poverty alleviation occurred at the expense of forest, but in only 4% of cases avoided deforestation was achieved at the expense of poverty outcomes. Negative outcomes

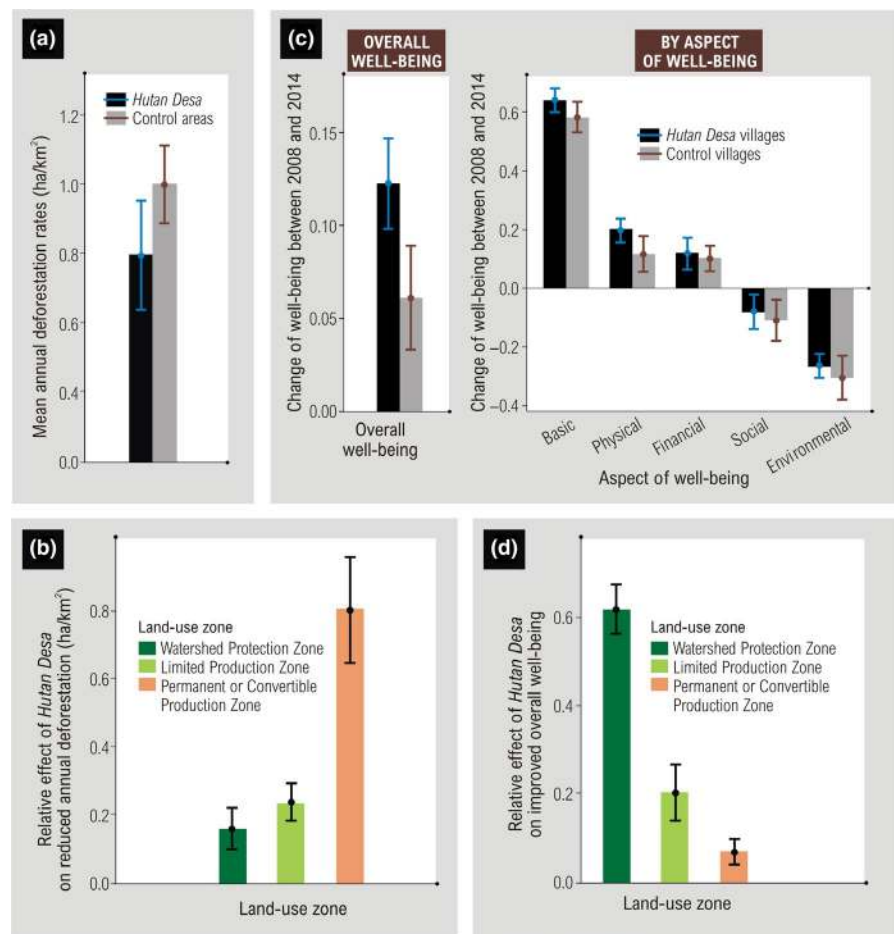


FIGURE 2 (a) Mean annual deforestation rates between 2010 and 2014 inside *Hutan Desa* and in control areas, and (b) relative effect of *Hutan Desa* on reduced annual deforestation partitioned by land-use zone. (c) Mean change in overall well-being and in different aspects of well-being between 2008 and 2014 in villages with *Hutan Desa* and control villages, and (d) relative effect of *Hutan Desa* on improved overall village well-being partitioned by land-use zones. Error bars represent 95% confidence intervals

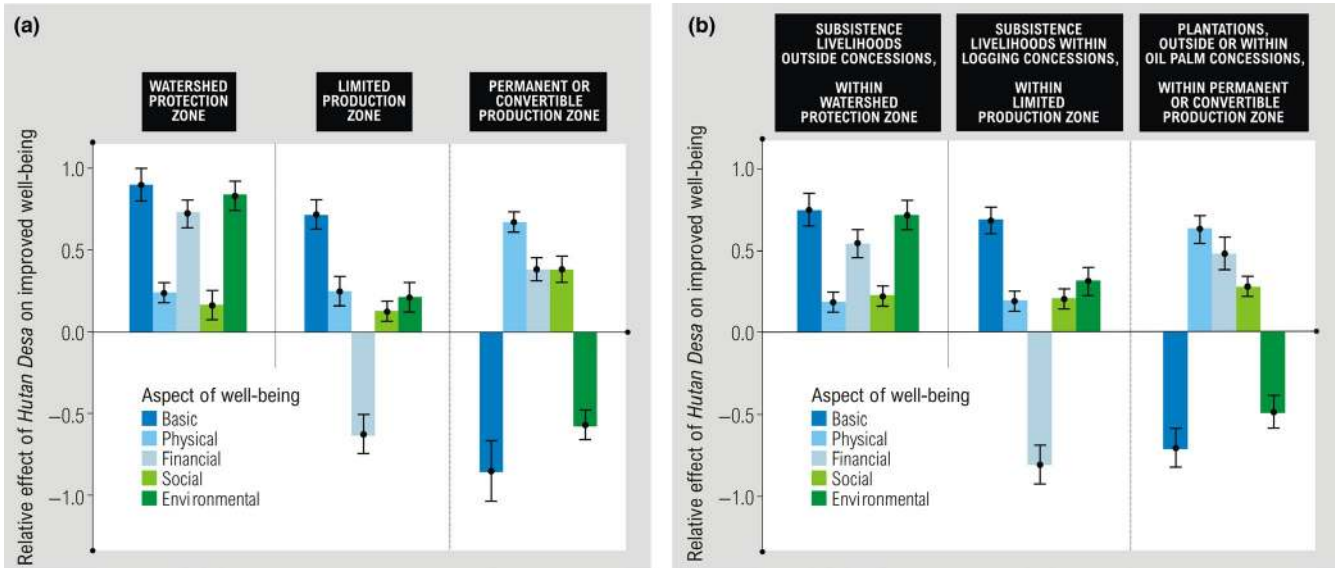


FIGURE 3 Relative effect of *Hutan Desa* on five aspects of well-being in Kalimantan between 2008 and 2014 in different land-use zones: Watershed Protection Zone, Limited Production Zone, and Permanent or Convertible Production Zone (a), and in different primary livelihood sectors: subsistence livelihoods outside concessions (within Watershed Protection Zone), subsistence livelihoods within logging concessions (within Limited Production Zone), and plantations outside or within oil palm concessions (within Permanent or Convertible Production Zone) (b). The effect of *Hutan Desa* is relative to areas without *Hutan Desa* that have similar biophysical and geographical characteristics

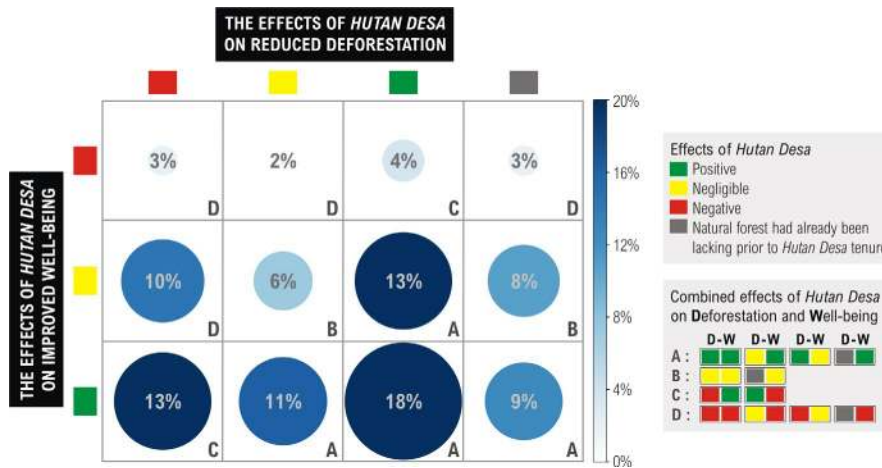


FIGURE 4 Proportions of *Hutan Desa* with varying effects on deforestation and well-being. Positive, negative or negligible effects of *Hutan Desa* on deforestation imply that deforestation rates within *Hutan Desa* are considerably lower, higher than or similar to those outside *Hutan Desa* areas with similar baseline biophysical characteristics. Positive, negative or negligible effects of *Hutan Desa* on well-being imply that improved well-being in villages with *Hutan Desa* occurs considerably faster, slower or at a similar pace as that in villages without *Hutan Desa* with similar baseline biophysical and socioeconomic characteristics. A total of 41 *Hutan Desa* management areas were assessed for well-being outcome and 32 *Hutan Desa* areas were assessed for deforestation (as intact natural forest was lacking in nine *Hutan Desa* areas before tenure). Positive outcomes for both conservation and well-being, or a positive outcome for one aspect and negligible for the other are labelled “A” (total 51% of cases). Negligible outcomes for both conservation and well-being are labelled “B” (14%). Trade-offs between conservation and well-being are labelled as “C” (17%), while negative outcomes for both conservation and well-being or a negative outcome for one aspect and negligible for the other are labelled “D” (18%)

for both conservation and well-being or a negative outcome for one aspect and negligible for the other were detected in 18% of cases (sum of cells D in Figure 4).

Impacts of *Hutan Desa* were also heterogeneously distributed across different land-use zones. Avoided deforestation was

strongest in the Permanent or Convertible Production Zone, followed by the Limited Production Zone and lastly, the Watershed Protection Zone. Conversely, improvements in our well-being indicators were strongest in Watershed Protection Zone, followed by the Limited Production Zone and then the Permanent or Convertible

Production Zone. Our findings are comparable to those of Ferraro and Hanauer (2011) on protected areas in Costa Rica (mainly composed of national parks and community-based protected areas, IUCN categories II and VI, respectively), which highlighted protected areas with the most avoided deforestation to be associated with the least poverty alleviation, and protected areas where conservation effectiveness was limited were associated with the most improved community well-being.

4.1 | Why do benefits vary across land-use zones?

The benefits of *Hutan Desa* were moderated by baseline conditions and pressures in the different land-use zones. *Hutan Desa* areas in the Watershed Protection and Limited Production Zones tend to be located in areas of high forest cover and away from major cities and roads (Figure S7). In these areas, anthropogenic pressure is generally low to moderate, and forest encroachment mainly arises from illegal logging and shifting cultivation by local farmers (Purwanto, 2016; Resosudarmo, 2004). Because anthropogenic pressure is mild, any reduced deforestation rates are also expected to be mild with the introduction of *Hutan Desa* tenure. Hence, community forestry schemes are well placed to maintain forest cover simply because the pressures on forests are inherently low. Communities here often lack basic facilities, such as health clinics and schools, have limited access to electricity, poor housing conditions and are dependent on wood fuel (Figure S8). Despite these conditions, malnutrition among infants is rare (Figure S8), most likely due to high food self-sufficiency and large variety of micronutrient-rich food sources, as is often typical of forest-dependent communities (Harper, 2002; Ickowitz, Powell, Salim, & Sunderland, 2014; Ickowitz, Rowland, Powell, Salim, & Sunderland, 2016; West, 2006). These communities often rely on subsistence livelihoods (farming, fishing and gathering of forest products; Figure 1c). *Hutan Desa* facilitation by external organizations in the Watershed Protection and Limited Production Zones has likely led to improved financial well-being according to our indicators and improved infrastructure compared to the counterfactual. *Hutan Desa* licenses have also provided tenure clarity and reduced illegal logging and forest encroachment by people from outside the village, which could explain why social conflict has declined and the environment reported to be better preserved than in areas without *Hutan Desa* (Figure S6d). This pattern of improved income and infrastructure provision and reduced social conflicts has also been observed in other studies of forest-dependent communities with CF (e.g. Rahut et al., 2015; Rasolofoson et al., 2017).

In Watershed Protection Zones, forests support livelihoods via non-timber forest products (Shackleton, Delang, & Angelsen, 2011). In Limited Production Zones, however, village areas typically overlap with active logging concessions (Figure 1c), and community livelihoods depend more on cash income from timber and concession-related employment (Casson & Obidzinski, 2002; Engel & Palmer, 2006). Unlike in Watershed Protection Zones where timber extraction is prohibited, *Hutan Desa* granted in Production Zones (i.e.

Limited and Permanent or Convertible Production Zones) are entitled to 50 m³ per year for non-commercial purposes. Constraints on commercial utilization of timber as a result of *Hutan Desa* designation have had negative impacts on income, thus reducing financial well-being of communities to a greater extent compared to counterfactual areas. The negative effect of *Hutan Desa* here is analogous to the impact of restriction in timber harvest endorsed by forest certification and reduced impact logging schemes, that is, logging operations that implement careful planning and control of timber harvesting to minimize environmental impact and waste that typically result from conventional logging. These schemes are generally less profitable than conventional logging (Burivalova et al., 2017), although over longer timeframes the expected profit is higher (Boltz, Holmes, & Carter, 2003).

Areas designated as Permanent or Convertible Production Zone are typically located in places of low forest cover, near to markets, cities and major roads, where oil palm plantations dominate (Figure S7) and infrastructure is nearby (Figure S8). Competition for land is high (Sahide, Supratman, Maryudi, Kim, & Giessen, 2016) and typically involves a complex network of actors and stakeholders (Santoso, 2016). Because anthropogenic pressure is strong, deforestation is typically high, and there is potentially much to be gained for conservation with the introduction of effective *Hutan Desa* tenure. A large proportion of communities in this zone depend on cash crops, mainly oil palm (Figure 1c), giving them livelihood options outside the forestry sector. However, employment opportunities are often distributed unequally among community members (Obidzinski, Andriani, Komarudin, & Andrianto, 2012); inequities that may reduce overall well-being in intensively managed landscapes (Rasmussen et al., 2018). These factors provide an explanation as to why improvement to financial well-being is comparatively lower in this zone due to *Hutan Desa* designation compared to locations in the Watershed Protection Zone (Figure 3). A reliance on cash crops, which encourages people to purchase processed foods with limited nutritional value and results in poor environmental conditions, may also explain higher infant malnutrition in these areas (Figure S8a; Gómez et al., 2013; Ickowitz et al., 2016). Forest protection can induce a spillover effect of agricultural expansion and intensification to sub-optimal areas that often require high fertilizer inputs (Didham et al., 2015; Duncan, Dorrrough, White, & Moxham, 2008). Excessive fertilizer usage has negative environmental effects particularly on water quality (Obidzinski et al., 2012), which explains why water pollution levels had reportedly increased in Permanent or Convertible Production Zone with *Hutan Desa* than those without (Figure S6e), particularly on peatland. The analysis of PODES data also indicates that the number of agricultural labourers was markedly reduced in villages with *Hutan Desa* in Permanent or Convertible Production Zone compared to villages without (Figure S6d). Agricultural intensification often requires higher labour input to increase production per hectare (Rasmussen et al., 2018). Given shortage in agricultural labourers, and combined with a decrease in farmland due to land scarcity, this could lead to a decrease in household production and income (Angelsen & Kaimowitz, 2001). These impacts are reflected

also in the reduction in the basic well-being indicator in these production zones with *Hutan Desa* relative to those without (Figure 3).

4.2 | Implications for CF investments

The Indonesian government has pledged to allocate extensive land to CF by the end of 2019, which presents great challenges in terms of capital requirements and distribution. Our study provides objective information to guide the focus and priorities of the *Hutan Desa* programme and investments as it develops (as summarized in Figure 5, and translated in Bahasa Indonesia in Figure S9), as well as lessons that are broadly applicable to schemes in other national contexts. For communities living within the boundaries of Watershed Protection Zones, investment in *Hutan Desa* or payments for ecosystem services could be directed towards improving basic living conditions (e.g. sanitation, education and health programmes; Sunderlin et al., 2005). As the proportion of indigenous communities is higher in Watershed Protection Zones and Limited Production Zones (Figure S3), *Hutan Desa* can additionally provide a platform for enhancing recognition of indigenous wisdom and knowledge of forest and nature (Boedhihartono, 2017). For logging communities within the boundaries of Limited Production Zones, the loss of income from timber production due to *Hutan Desa* designation is likely to emerge as an issue and a potential source of social conflict (van Hensbergen, Bengtsson, Miranda, & Dumas, 2011). Therefore, in addition to improving basic living conditions, investment should also be directed towards compensating livelihood losses by introducing income

generating activities that allow communities to manage forests sustainably (van Hensbergen et al., 2011). For communities within the boundaries of Permanent or Convertible Production Zones where cash crop plantations are the dominant livelihood sector, land availability for plantations is reduced by CF, leading to increased pressure to intensify agricultural production. Because smallholders and company plantations exist in this zone, the success of *Hutan Desa* management will require close cooperation with both sectors. For smallholders, investment could be directed towards provision of agriculture inputs, including training and access to technical recommendations on sustainable agriculture practices (such as those related to fertilizer use and zero-burning land clearing; Lee, Ghazoul, Obidzinski, & Koh, 2014; Soliman, Lim, Lee, & Carrasco, 2016), and introducing additional income sources from community protected forest programmes to reduce vulnerability to shocks (Schroth & Ruf, 2014). For company plantations, enhanced environmental monitoring and inspection of pollution and environmental hazards is needed, as well as strong enforcement of environmental laws and policies, to ensure these hazards do not spill over into neighbouring CF areas.

The amount and complexity of tasks required to manage *Hutan Desa* on land within Permanent or Convertible Production Zones is substantial compared to what is required on other land designations considered in our analysis (Figure 5 and Figure S9). However, the extent of deforestation that is avoided due to *Hutan Desa* in this zone is also greatest (Figure 2b). This implies that safeguarding forests within Permanent or Convertible Production Zones provides substantial additional conservation benefits per hectare.



FIGURE 5 Preliminary guidelines (based on this study) for future *Hutan Desa* policy and focus of investments in different land-use zones in Indonesia: Watershed Protection Zone, Limited Production Zone and Permanent or Convertible Production Zone

4.3 | Study limitations and caveats

Potential caveats include model limitations (simplifying assumptions and omission of important confounding variables), transfer of our results into novel temporal contexts (particularly different climatic regimes), and choice of well-being indicator to assess the outcome in the CF assessment. Our analytical assumptions reflect the availability of data at jurisdictional scale. For instance, we included only provincial boundaries, NGO partnerships, primary livelihood of communities and well-being condition prior to CF designation as sociopolitical factors that could confound the evaluation of *Hutan Desa* performance. Omission of important confounding variables that are positively correlated with CF assignment and our outcome indicators could also affect the reliability of conclusions derived. However, our sensitivity analysis indicates that if such confounding variables exist, they would need to increase the likelihood of *Hutan Desa* designation by a factor greater than at least 1.81 (Table S5), thus implying that our matching analysis is robust. Additionally, we used deforestation rate as an indicator of forest conservation, as this the most commonly used measure available. However, forest conservation is not just about curbing deforestation, but also curbing forest degradation and encroachment, which typically operate at much finer scales and therefore are difficult to measure and apply as indicators of conservation success.

Our analysis on avoided deforestation was performed on data between 2010 and 2014 to roughly match the time period covered by the well-being analysis (PODES indicators). The deforestation pattern in Kalimantan is known to be affected by climate conditions, where severe drought during a strong El Niño phase could escalate fire-induced deforestation (Field et al., 2016; Herawati & Santoso, 2011). During the severe El Niño drought year in 2015 (Figure S3), *Hutan Desa* in Permanent or Convertible Production Zone, particularly on peatland, performed poorly in preventing deforestation due to wildfire (Gaveau et al., 2018; Santika et al., 2017). Therefore, the avoided deforestation we detected reflected anthropogenic factors, and might not hold during periods of extreme climatic events.

Some of the well-being indicators we used focus on the prevalence of socioeconomic programmes, such as cooperative schemes, credits and small businesses. While information about the rates of community participation could provide a better proxy for well-being than merely the prevalence of these programs, such data are unfortunately not available in the PODES dataset over the spatial and temporal scale of our study. Moreover, we were restricted to objective and material well-being indicators. There is growing recognition of the need to include subjective non-material indicators in poverty assessment, such as intrinsic values related to culture, ethnicity and social embedding or spiritual attachment to places (Biedenweg et al., 2014; Breslow et al., 2016; Russell et al., 2013). Unfortunately, in many developing countries, including Indonesia, such data are typically unavailable at broad geographical scales. Where such data do exist, we encourage researchers to include them within CF assessments, and explore ways to scale up beyond local-level appraisals in

order to provide comprehensive assessment of both objective and subjective well-being.

4.4 | Conclusions

Our study highlights that the successful implementation of CF, where forest conservation is implemented, will require investment in different activities in different land-use zones to support transition of livelihoods and to prevent exacerbating environmental degradation, poverty, and socioeconomic disparity. We provide a robust framework for monitoring and evaluating CF, and an appraisal of performance over the first five years of Indonesia's leading CF scheme, which can serve as a crucial baseline for long-term monitoring. This monitoring and evaluation framework has broad applicability for other countries implementing community forestry.

CONFLICT OF INTEREST

Nothing to declare.

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AUTHORS' CONTRIBUTIONS

T.S., M.J.S., K.A.W., S.B., A.K. and E.M. conceived the ideas and designed the study; A.K., J.A.H. and T.P.I. consulted government agencies in Indonesia to collate the spatial data and provide local interpretation; F.A.V.St.J. and R.F. provided insights on poverty methodologies and selected the indicators together with T.S. and M.J.S. T.S. undertook analyses and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

DATA ACCESSIBILITY

The data used for analyses are publicly available under license via Indonesia's Bureau of Statistics (<https://mikrodata.bps.go.id/mikrodata/index.php/catalog/PODES>), and University of Maryland (http://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.6.html). Data linking specific community forest areas with poverty and/or deforestation outcomes will not be made

available for public distribution due to sensitivities concerning these findings in local decision making. However, summaries of the data will be made available by June 2019 via the project website (<https://research.kent.ac.uk/meps/>), and data may be granted by request to the corresponding author, and with permission of all parties involved with the research.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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