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Prospects and problems: considerations for smallholder cattle grazing in oil palm plantations in South Kalimantan, Indonesia

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Abstract Current Indonesian beef production only meets 45% of local demand. Increasing local beef production through integration of cattle production in pre-existing oil palm plantations is a possible solution to meeting this shortfall. The oil palm understorey provides feed, alleviating the need to convert additional land to agriculture. Smallholders are important contributors to both Indonesian cattle and palm oil production. This case study research seeks to understand key aspects of smallholder cattle management in palm oil production areas, to highlight opportunities and barriers to cattle integration. Thirty-nine smallholder cattle farmers from four villages in South Kalimantan were individually interviewed. The lack of alternative feed sources was the major driver towards the adoption of cattle production using oil palm understorey as feed. Cattle grazing was uncontrolled due to labour shortages and occurred in individually owned and 'plasma' plantations, with cattle penned at night where possible to avoid theft. Arrangements on land access and use between stakeholders are needed for systematic cattle grazing and to control cattle theft.

Keywords Crop livestock systems · Smallholder agriculture · Farming systems · Grazing systems · Cattle management · Silvopasture

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Introduction

Current domestic Indonesian beef production satisfies only 45% of annual demand: the remaining 55% is imported (Direktorat Jenderal Peternakan dan Kesehatan Hewan 2020; Smith et al. 2018). Furthermore, it is estimated that beef consumption, currently at 2.4 kg/head/annuum (OECD 2021) will increase by 10.3% by 2025, and double by 2045 (Arifin et al. 2018; Priyanti et al. 2012; Smith et al. 2018), leading to more pressure for domestically produced meat. Smallholders produce 90% of domestic beef (Agus and Widi 2018) and therefore play a critical role in increasing local beef production.

In view of local beef production deficit and to decrease dependency on imported beef, the Indonesian government launched the 'beef self-sufficiency

programme' (or *Program Swasembada Daging Sapi*) in 2000 (Agus and Widi 2018). This programme had a target to reduce beef imports by 10% in 2014 by increasing the number and productivity of the domestic herd (Gayatri and Vaarst 2015). The efforts included promotion and assistance for artificial insemination, improvements in animal disease control, improvement of cattle feed and banning the slaughter of productive breeders (Mahendri 2019). However, these measures have not led to significant increases in national herd size with low fertility, low conception rates and constrained access to markets continuing to constrain Indonesian cattle production. These constraints are further compounded by restricted land availability and limited access to affordable, locally available and good quality cattle feed (Agus and Widi 2018; IndoBeef 2018; Lisson et al. 2010; Mahendri 2019; Mastika 2003; Matondang and Talib 2015; Rondhi et al. 2019; Talib et al. 2003).

Integrating cattle in oil palm plantations is a possible solution to these constraints. Large plantation areas are available for grazing and the plants growing under the canopy (the understorey) are a potential feed source. Cattle-oil palm integration also has additional potential benefits; supplementary income, reduced weeding costs and increased soil quality through the return of manure (Devendra 2008; Quartermain 2004; Stür et al. 1994). Oil palm is perhaps Indonesia's most important agricultural product, with 35 million tonnes of crude palm oil produced annually from over 14.3 million hectares planted (Perkebunan 2019). Despite cattle-oil palm integration being a government priority since 2003, little progress has been made to scale out systems and quantify the benefits, particularly for smallholder cattle farmers.

The few oil palm plantations involved in cattle production show much diversity: from cattle grazing and residing in the plantation to being continuously penned and hand-fed; from large-scale commercial plantations to smallholder plantations; a large range of cattle production enterprises (finishing, breeding or mixed); a variety of cattle ownership systems (full ownership to profit-sharing schemes); and an array of options for feeding, reproduction and marketing (e.g. Fawzi Hj et al. (1998); Latif and Mamat (2002); Riswani et al. 2012). The relative success of the various management systems has not yet been assessed and there is a need for the development of sustainable models of cattle-oil palm integration which meet environmental, social and economic requirements for adoption by smallholders or commercial plantations.

Smallholder farmers currently own 40% of the area under oil palm in Indonesia (Gatto et al. 2015; Rival and Levang 2014) and are expected to soon dominate the sector, both in area and production (Rival and Levang 2014). Smallholders have been involved in oil palm cultivation since the 1980's, through the governmental transmigration programme, relocating people from densely populated islands (Java, Bali, Lombok) to less densely populated islands such as Kalimantan in order to support economic development in these rural areas (Adhiati and Bobsien 2001; Gatto et al. 2015; Zen et al. 2006). Transmigrants received land, a house and agricultural support in the form of extension services (Adhiati and Bobsien 2001). Distributed land is at the periphery of governmental or privately managed oil palm plantations and is under contractual ties: the land is managed by the company, the smallholder receiving compensation for the sale of the oil palm fruit (Rival and Levang 2014), resulting in a system called plasma-nucleus. The 'plasma' is the areas of smallholder contracted plantations, while the 'nucleus' is the privately-managed commercial plantation (called 'estate' from here on). Currently, reduced importance of government support programmes and the emergence of competing firms in the palm oil value chain (mills, transporters and plantation developers) enables smallholders to become independent and allows them to deliver fruit bunches directly to mills (Euler et al. 2016; Rival and Levang 2014).

The importance of smallholders in Indonesian oil palm and cattle production make it pertinent to research the potential for smallholder involvement in cattle production under oil palm plantations. There is a dearth of literature on the integration of smallholder cattle grazing into oil palm farming systems in Indonesia (Bremer et al. 2022; Henuk et al. 2018). In particular, understanding how smallholder farmers manage cattle in palm oil producing areas, and their views on cattle-oil palm integration is essential information to understand the efficacy of these integrated farming systems.

Hence, the aim of this research was to understand smallholder cattle farmers' reasons for and means of managing cattle in palm oil producing

areas, specifically looking at feed management and the use of the oil palm plantations for grazing. Benefits and constraints of smallholder cattle production in oil palm plantations will be highlighted and suggestions for future development will be presented. This case study concentrated on smallholder cattle farmers in oil palm production areas of Kalimantan, the second-largest oil palm producing island of Indonesia (Badan Pusat Statistik 2019), and captured their perspectives through in-person interviews.

Materials and methods

Description of study area

The case study research took place in the Tanah Bumbu district of South Kalimantan, Indonesia (Fig. 1). Recently (2011–2019), the area of oil palm cultivation in Kalimantan (consisting of 5 provinces including South Kalimantan) has more than doubled, with palm oil production increasing over 250% (Badan Pusat Statistik 2019a). In 2019, Kalimantan produced close to 17 million tonnes of fresh fruit bunches, accounting for 37%

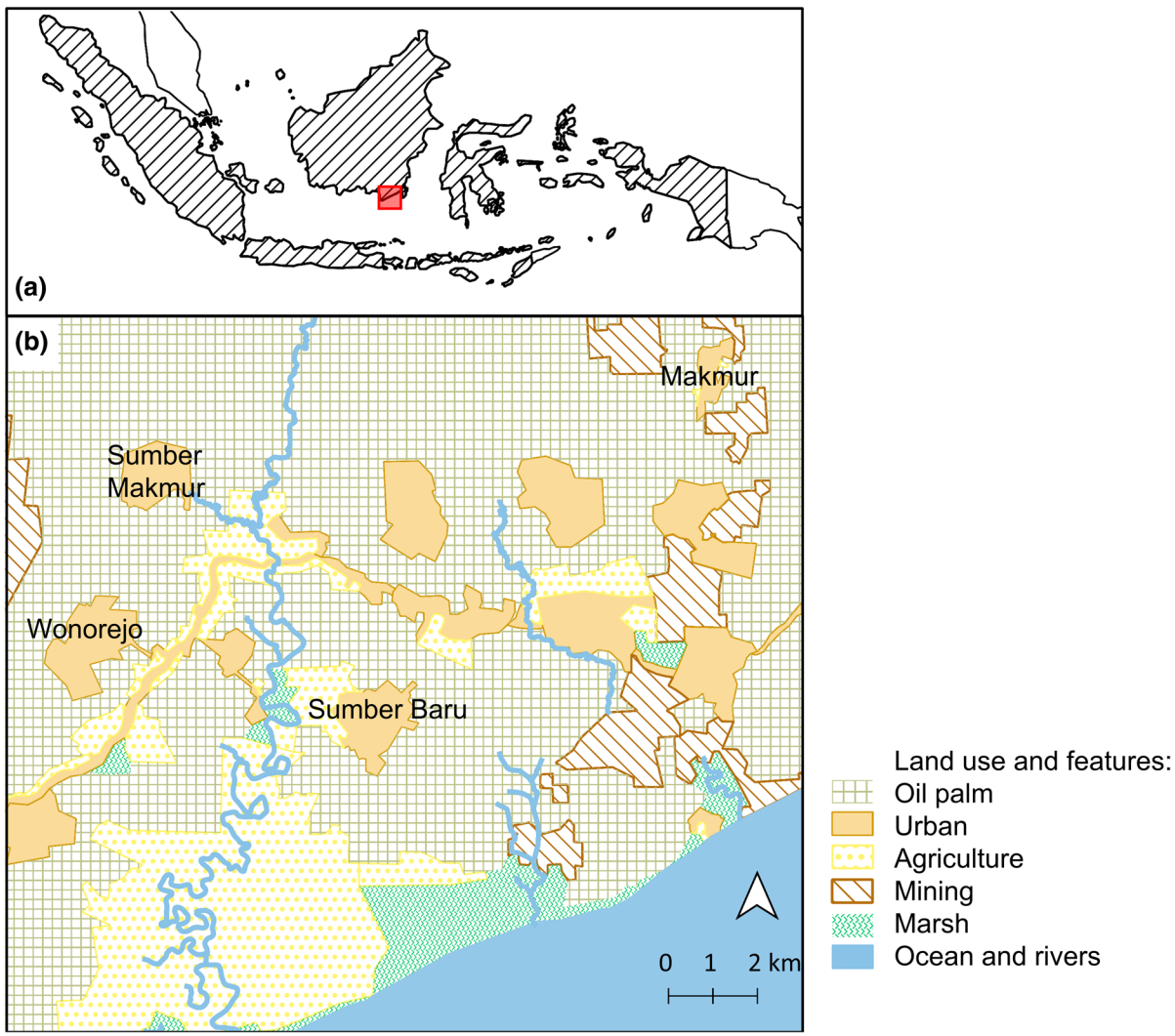

Fig. 1 Location of the study site in Indonesia (**a**) and land use map of the area (**b**). Maps by J. Bremer, based on Google satellite imagery (Google Maps n. d.)

of Indonesian palm oil production (Badan Pusat Statistik 2019b). The Tanah Bumbu district houses 20,667 head of cattle, 12.5% of total South Kalimantan cattle population (Badan Pusat Statistik 2021). More than 50% of local beef demand is however met through frozen beef and live cattle imports (5,000 head of cattle are imported in South Kalimantan monthly Hamdan et al. 2019; Rohaeni et al. 2019)).

We recognise the rapid land-use change in favour of palm oil plantations is associated with a number of environmental and social issues. Not only does oil palm expansion directly lead to deforestation and biodiversity, wildlife and ecosystem losses (Fitzherbert et al. 2008), it is associated with high risk of indirect land-use change: displacement of land originally devoted to food or feed production and clearing of land with high carbon stocks (e.g. primary or secondary rainforests, peatlands and wetlands (Oosterveer 2015)). Although cultivating oil palm is associated with poverty alleviation and rural development, there are other social concerns including the expansion of plantations at the detriment of indigenous communities, social conflicts on access and ownership of land, and the absence of informed consent and unequal benefit sharing (Rist et al. 2010; Thoenes 2006). The study area consisted of a privately managed forest for timber production before the establishment of the palm oil plantation in 1995.

The research was conducted in four villages: Sumber Makmur and Wonorejo, in the Satui sub-district of Tanah Bumbu, and Makmur and Sumber Baru, in the Angsana sub-district of Tanah Bumbu. With the exception of Sumber Baru, all villages were surrounded by oil palm plantation with a natural understorey (Fig. 1). The north-western side of Sumber Baru was bordered by agricultural land planted with rice, all other directions were bordered by oil palms.

There were two main models of smallholder oil palm management in the area: (1) independent oil palm farming, where participants owned and managed their plantation and sold the fresh fruit bunches and (2) contracted oil palm farming (colloquially known as 'plasma' farmers), whose land was managed by an estate, and who received a regular remuneration from the estate reflecting the plot's productivity.

Selection of interview participants

All activities in this research were approved by the University of New England Human Research Ethics Committee (approval HE19-156). The only selection criteria for study participant was the ownership of at least one head of cattle. Participants were contacted through the village head, the local cattle farming group or the extension service from the local Department of Plantations and Animal Husbandry (Dinas Perkebunan dan Peternakan Provinsi Kalimantan Selatan). Only (self-identified) household heads were interviewed. If farmers were willing to participate in the interview a meeting time and date was arranged. Although the interviews were individual, several participants would generally assemble in a communal space to be interviewed sequentially. Thirty-nine participants were interviewed. A higher number of interviews were conducted in Sumber Baru village (n = 17), followed by the villages of Wonorejo (n = 9), Sumber Makmur (n = 8) and Makmur (n = 5).

Interview methodology

When conducting the in-person interviews in Indonesian, the participant, researcher and translator were present, the translator also scribed. The interview followed a structured set of open- and closed-ended questions on the following topics. Firstly, general information was obtained to profile the interviewee: age, education, main occupation, years of experience in farming (oil palm, cattle and/or other), involvement in other paid occupations. This was followed by a set of questions on: the area and ownership of farming land, the number and breed of cattle, ownership system and production system (cattle finishing and/or cow-calf raising). Next, participants were asked about their reason/s for having cattle, their adopted cattle management strategy and use of grazing. Finally, participants were asked to share their views on cattle-oil palm integration, whether they had particular reasons for supporting it or not and if they faced any problems related to cattle-oil palm integration.

Statistical analyses

All statistical analyses were conducted in R (version 3.6.3 (2020-02-29)). Where appropriate, tests of difference were conducted by Wilcoxon rank sum test or One-way ANOVA followed by Tukey HSD.

Results

Smallholder farmer profiles

Settlement history

All smallholders interviewed were immigrants who moved to South Kalimantan as part of the Indonesian government-supported transmigration scheme for palm oil. The earliest year of arrival was 1980, while the latest year of arrival was 2018. The mean year participants commenced farming in South Kalimantan was 1997: 30% started farming before 1990 and 18% started farming after 2009. Origins varied between villages: farmers in Sumber Baru were from Central Java; in Wonorejo farmers came from East Java; in Makmur farmers were from Lombok, and in Sumber Makmur farmers came from both Bali and Java.

Gender, age and education

Interviews were dominated by men, with the presence of one woman only, in Sumber Makmur village. All interviewees were over the age of 30, with the majority between 45 and 64 years of age and 36% of participants over 64 years of age. All participants were first generation transmigrants. Age was related to the year of transmigration: generally, participants who were older had immigrated earlier (Fig. 2, Tukey HSD pairwise comparison p value = 0.041 when comparing age classes 30–44 to over 65-year-old participants). Mostly, the next generation had not (yet) taken over the farm since they were working or studying in urbanised areas, or were still too young.

Although 8 of 39 participants had not received any form of education, the majority had completed primary education (20 of 39). Eight farmers had completed middle school (6 years in addition to primary education).

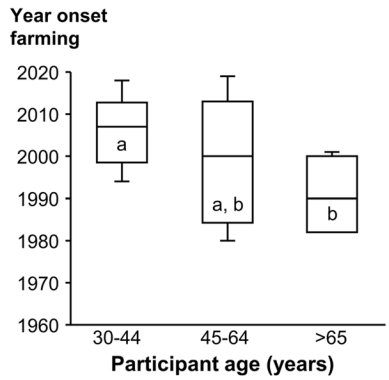

Fig. 2 Year of onset farming according to participant age class (30–44 years, 45–64 years and over 64 years). Letters a and b indicate differences in year of farming onset between the age categories ($P < 0.05$, Tukey HSD test)

Wonorejo was the only village where some smallholders (3 out of 9) had received vocational education.

Main occupation and oil palm ownership patterns

No participants were exclusively cattle farmers: on average the number of occupations per participant was two, in addition to cattle raising. A total of six to seven different occupations were undertaken in each village (Table 1). In Sumber Makmur rubber production, individual palm oil production and plasma palm oil production were prevalent occupations involving at least 4 out of 8 participants. In Makmur a large proportion of participants (4 out of 5) were involved in both plasma palm oil and/or rubber production. Rice cultivation occurred in Sumber Baru village only, involving 15 out of 17 participants. No other occupation was undertaken by more than 50% of the participants from this village. In Wonorejo the diversity of occupations per participant was lowest, with participants having on average only one occupation besides cattle husbandry. Occupations undertaken by less than 35% of participants in each village were: labouring, working for the oil palm estate, raising chicken, producing vegetables and working as a government official (Table 1).

Cattle farming experience and farmers' reasons for cattle husbandry

Experience in cattle farming was diverse, ranging from over 20 years (8 of 39) to less than 3 years (11

Table 1. Heatmap showing the percentage of participants per village and occupation

Occupation (% of participants per village)	Makmur (n=5)	Sumber Baru (n=17)	Sumber Makmur (n=8)	Wonorejo (n=9)
Cattle husbandry	100	100	100	100
Palm oil production (plasma plantation)	80	47	75	44
Palm oil production (individual plantation)	0	24	63	0
Rice production	0	88	0	0
Rubber production	80	24	50	22
Labouring	20	6	13	33
Employment at the palm oil producing estate	0	12	13	11
Chicken raising	20	0	0	11
Vegetable production	0	0	0	11
Government officer	20	0	0	0

A separation is made between oil palm plantations that are managed individually or by the estate (plasma plantations). Darker cells show a higher proportion of participants per village practicing the relevant occupation. Participants have multiple occupations

of 39). Half the participants began raising cattle as soon as they settled in Kalimantan.

The reasons for keeping cattle were income (16 of 39) closely followed by wealth creation (savings, 12 of 39), and finally increasing household standard of living (8 of 39). These reasons overlap to a degree, as illustrated by the following responses 'I am optimistic cattle production is a good way to get more income' and 'I saw my friend's standard of living increase through cattle production and I wanted that as well'. Less than 20% of smallholders gave the following reasons for cattle husbandry, ranging from the most to the least mentioned: a source of money in case of emergency, for school fees, as a hobby, to buy a house or assets, because of cultural norms. An illustration of the importance of cultural norms is the following statement 'I am from Bali, so I raise cattle'. Personal consumption was not a strong motivating factor for cattle husbandry, as cattle were usually sold and only occasionally slaughtered as part of special events or ceremonies such as weddings or Qurbani (the ritual animal sacrifice of livestock during the Islamic month of Dzul Hijjah).

Cattle herd characteristics

Participants either owned cattle and/or participated in profit-sharing programmes. In Makmur and Sumber Makmur the breeder cows for the profit-sharing scheme originated from other farmers within the village, members of the local farmer groups. In Sumber Baru and Wonorejo the contracting project was a government programme: when provided with a breeder cow the farmer had to return two calves within five years but retained the breeder cow. The returned calves were redistributed to other households in the region (Hadi et al. 2002). With one exception, all participants who started farming cattle before the year 2000 owned their cattle herd in full (8 of 39 smallholders). Among the 10 participants who started cattle farming after 2014, only 3 owned their full herd. Furthermore, four participants in Sumber Baru explained having recently transitioned from contract

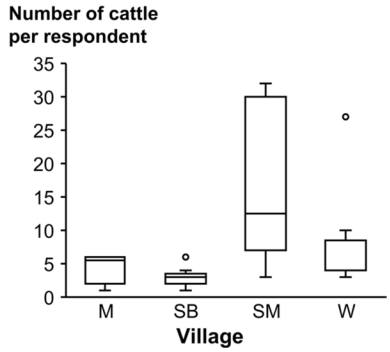

Fig. 3 Participant herd size per village: Makmur (M), Sumber Baru (SB), Sumber Makmur (SM) and Wonorejo (W)

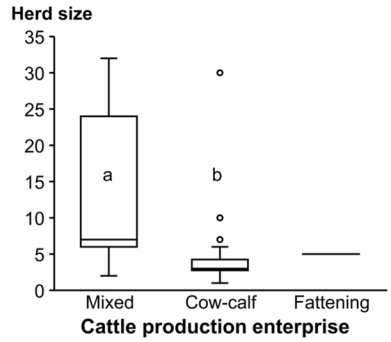

Fig. 4 Herd size for farmers with finishing, cow-calf, or mixed cattle production enterprises. The letters a and b show significant difference in median herd sizes (Wilcoxon rank sum test)

cattle-raising to owning their cattle. On average, participants with only self-owned cattle started cattle production in 2001, participants with only contracted cattle started in 2011, and farmers with both owned and contracted cattle started in 2008. A rough estimate of the transition period from only contracting to only owning cattle is therefore 10 years.

On average, households had 4 head of cattle in their herd. Seven participants had 10 or more head of cattle: 5 of these were from Sumber Makmur (Fig. 3).

The common cattle breed was the Indonesian "Bali" (*Bos javanicus*). Two farmers in Wonorejo had acquired 1 and 2 head of Limousin bulls through the governmental finishing contracting programme. Both these participants also had Bali cattle and total herds of 7 and 10 head of cattle. One farmer from Sumber Baru had one Brahman cow, part of the governmental contracting programme for breeding, in addition to two head of Bali cattle contracted for breeding.

All three cattle enterprises (cow-calf, mixed and finishing enterprises), were present at the study site (Fig. 4), although only one farmer specialised in cattle finishing. Ninety-eight percent of participants therefore had breeding stock, with just under a third of them keeping calves for fattening, resulting in 12 participants practising a mixed cattle production enterprise. Median herd size was significantly larger in mixed enterprises compared to breeding enterprises (Wilcoxon rank sum test, $P = 0.0018$).

Current cattle management

This section commences with the reasons why some participants have not considered the oil palm understorey for cattle feed. Then followed by an examination of the drivers behind the adoption of cut and carry from the oil palm plantation, and concludes by exploring the drivers behind the adoption of cattle grazing in the plantations.

Ten out of 39 participants did not use the oil palm understorey as a feed source. Eight were from Sumber Baru village, the only village where rice was grown. The main driver for farmers keeping cattle in pens and using cut and carry forage (a feeding system where fresh grass is cut daily and carried to the penned cattle) was the limited availability of understorey in the oil palm plantation, resulting in large distances cattle needed to travel for feed. As one farmer explained: "There is no grass in the oil palm plantation, and the cattle would have to travel too far". Cattle feed consisted of rice residue and vegetation collected from the rice fields and along roads. Additional reasons for keeping cattle in pens were: protecting cattle against theft (n = 4), avoiding damage to rice fields (n = 2), and because animals were more content and gained weight more rapidly in pens (n = 1). One participant from Sumber Baru let the cattle graze in the rice paddies during the day, under close supervision to avoid the destruction of the paddy land. Cattle were herded into pens at nightfall for safety reasons. One participant from Wonorejo village did not use oil palm understorey as cattle feed: they collected feed near the river in order "to keep busy".

Cattle theft was a major concern of many participants. They described stock theft in the following manner: while cattle grazed, thieves arrived in trucks, shot the cattle, loaded them on the trucks and drove

off. Participants stated they could not stop cattle theft since thieves were usually armed. The risk of cattle theft was said to be greatest immediately before Qurbani (religious festival), explained by the increased demand for beef.

Of the 29 smallholder farmers using the oil palm plantation as a feed source, two chose to exclusively feed their cattle by means of cut and carry. For one participant this was in order "to keep busy" since the 10 head of cattle were their main source of income together with vegetables fertilized using cattle manure. Since cattle husbandry was their main activity they devoted time to collecting forage located in the oil palm plantation (a daily distance of up to 15 km was travelled in this process). The second participant using cut and carry only had one head of cattle: they explained it was easy to collect enough feed, even though they also raised chicken and managed rubber trees. In both cases, the smallholders were able to meet the labour demand of cut and carry.

The majority of participants (27 of 39) grazed cattle in nearby oil palm plantations, whether individually managed or 'plasma' areas. In addition, 5 participants also cut and carried forage from the oil palm plantation during the dry season, when feed availability was lower (compounded by concerns over cattle travelling 'too far' and increased risk of cattle theft). The remaining farmers (22 in total) grazed cattle in the plantation all-year-round.

Five participants were seemingly more risk-averse and kept a portion of their herd penned. Two farmers kept the cattle ready for sale in the pens for safety reasons, while three farmers kept pregnant cows, lactating cows and young calves in pens to ensure they were taken care of, did not get trampled by other cattle, or attacked by wild dogs. These farmers had herd sizes from three to 30 head, with a median of seven, showing that risk-aversion was not directly related to herd size.

Smallholders applied one of two grazing strategies: all-day-round grazing (6 participants of 27) or day-time grazing with overnight penning (21 of 27). First and foremost, concern over cattle theft at night led to night-time cattle penning (16 of 27). This sentiment was supported by comments from four out of six farmers who grazed cattle all-day-round explaining that this practice was implemented reluctantly as their cattle were "too wild to pen". These farmers were interested in learning about cattle handling, so that cattle could be penned at night, reducing risk of cattle theft. Feed availability in the plantation was a big driver for cattle grazing in the plantation, since there were no other feed sources available and it was viewed as 'free' feed without labour or economic inputs required (10 of 27). For 8 smallholders the reasons for cattle grazing in oil palm plantations were restricted labour availability and long carting distances to cut and carry feed. Five of these participants had other full-time jobs (labouring, government officer and merchant), while the remaining 3 had independently owned oil palm plantations or rice fields to manage. A total of 7 participants suggested grazing in the oil palm plantation was advantageous for cattle health, with cattle weight gain and a healthy appearance.

When grazing in the oil palm plantation, 15 out of 27 participants intermittently herded or checked their cattle (e.g. afternoon herding or checking on cattle twice a day), while the remaining 12 monitored cattle closely while grazing. Both herding models were adopted in order to reduce the risk of cattle theft (21 of 27). The feasibility of highly vigilant (fulltime) herding was dependent on participant labour availability (15 of 27).

There was no set grazing rotation in any of the villages, cattle moved freely (17 of 27) or were herded to places in the oil palm plantation with highest feed availability (7 of 27). Three farmers herded cattle fulltime to ensure their cattle did not get lost or travel too far. The usual distance travelled by cattle when grazing was 1–5 km from the household dwelling, depending on feed availability and the cattle's mobility and temperament.

With the exception of some farmers providing cut and carry forage from the plantation at night, no additional feed was provided to grazing cattle. Oil palm processing by-products (e.g. palm kernel cake) were not used as cattle feed, with the exception of freshly pruned palm fronds opportunistically consumed by cattle when grazing.

Smallholder farmers' perspective on cattle-oil palm integration

For all smallholders using the oil palm understorey as feed, its availability was crucial for cattle production since alternative feed sources were lacking. As one participant stated: "In the absence of the plantation, it

would be impossible to have cattle grazing". In addition, one farmer explained the oil palm plantation was preferred over rubber plantations for grazing since cattle may disturb rubber collection. Another participant said oil palm plantations are a better feed source than mining sites, as "cattle get stuck on the slopes and mud of mining sites, and risk getting poisoned from drinking polluted water".

In Sumber Baru village, where rice was grown, less than half the participants used oil palm understorey as feed, instead feeding rice residues and grasses which they preferred, since "there is no feed in the plantation, if there was more grass my cattle would graze in the plantation".

Often cattle owners were alerted by plantation workers of agrochemical applications. Consequently, about half the participants who grazed cattle in oil palm plantations steered clear of the area for 5 to 6 days to avoid any ill-effect on their cattle. One smallholder farmer indicated that the effects of herbicide had little consequence on animal health, and they therefore did not avoid the areas with recent agrochemical application.

Another implication of herbicide application as raised by four smallholders was that it reduces cattle feed availability. On the other hand, one of them tried to make the most of oil palm management by grazing their cattle in recently pruned oil palm blocks, making freshly pruned oil palm fronds available as cattle feed. An opinion raised by two participants was that cattle grazing is beneficial for the oil palm plantation, through manure production and weed control by grazing.

Discussion

Cattle production was an attractive activity for smallholder farmers in the study area as shown by a number of participants who had recently commenced their cattle production enterprise. Cattle were valued for economic stability, for insurance in times of emergency and they hold socio-cultural importance (Anderson 2003; Rohaeni et al. 2019; Widi 2015; Zali 2019). Nevertheless, all participants relied on other income sources. In smallholder farming in Indonesia it is generally accepted that cattle, although important, are secondary to crop farming (Agus and Widi 2018). The reliance on other income sources for household livelihood might reduce the capacity of smallholder farmers to invest land, time and labour in scaling-up cattle production. Although this study looked at cattle production in palm oil producing areas, opportunities exist to explore the potential of small ruminant production under oil palms.

Labour availability and the risk of cattle theft were the two most important determinants of cattle management when grazing. Labour availability determined time spent herding during the day, and when possible, all smallholder farmers penned cattle at night to avoid cattle theft. For those participants for whom cattle penning was not feasible, a training opportunity exists to improve competencies in animal handling to ensure easier control. The risk of cattle theft highlights the need to increase cattle stock security when grazing. Zamri-Saad and Azhar (2015) and Tohiran et al. (2017) report cattle theft as an outstanding problem for large oil palm plantations in Malaysia, whereas Rohaeni and Hartono (2014) highlight it as a threat for smallholders in South Kalimantan specifically. In Australia, an important pathway towards preventing cattle theft is the 'National Livestock Identification Scheme', which tracks individual animals from birth to slaughter (Anderson and McCall 2005). This solution might not fit seamlessly into the Indonesian environment due to the large number of smallholders involved in cattle production, so more culturally sensitive strategies for reducing cattle theft should be developed. Communal penning was originally developed to prevent poaching, by ensuring constant supervision (Dahlanuddin et al. 2016). In a similar way, communal grazing might be a deterrent against cattle theft, although it might not offer sufficient protection against armed poachers.

In Sumber Baru, where rice was produced, oil palm plantations were not perceived as a reliable feed source. The perception of insufficient feed quantity was most likely related to the relative availability of alternative feed sources in the form of rice residues and weeds from cropping areas, although understorey availability may be lower in the surrounding oil palm plantations (e.g. due to older plantations or the use of herbicides (Wong et al. 2005)). Labour-efficiency was also higher for these farmers when collecting feed from nearby cultivated lands rather than more distant plantations. The use of oil palm processing by-products for feed is a missed opportunity for cattle oil-palm

integration. Increased access for local smallholders to these by-products could increase cattle productivity (Suryana and Yasin 2015).

An additional solution to improving cattle productivity is introducing forage species which increase understorey availability, persistence and quality (Kaligis et al. 1995; Wilson and Ludlow 1991): although volunteer species are persistent under local management conditions, their productivity is generally low (Stür and Shelton 1991). In Malaysian oil palm plantations, understorey availability three years after planting was between 6 and 10 t dry matter (DM) per hectare but decreased to 0.4 t DM/ha four years later after full canopy closure (Chen 1991; Wan Mohamed et al. 1987). The use of the shade-tolerant forage *Stenotaphrum secundatum* is a promising forage species in young oil palm plantations but is untested in older plantations with closed canopies (Hutasoit et al. 2020). Although suitable introduced forage species have been identified for coconut plantations, more research is required on suitable understorey species for oil palm plantations, where light transmission is lower (Bremer et al. 2022). In addition, the possible barriers to adoption and the profitability of introducing understorey species needs to be examined (capital and labour investments and returns generated (Mullen 1995)).

Understorey was a crucial feed source for those smallholders without access to alternative feed sources (e.g. communal grazing land or crop residues). These smallholders viewed the plantation understorey as 'free feed' which required minimal labour and financial contributions. Combined with individual cattle management, the perception of 'free feed' raises the issue of 'tragedy of the commons', where overconsumption of the communal resource eventually leads to everybody's detriment. In this scenario the overuse of the understorey might lead to overgrazing and the depletion of feed resources.

The transmigration scheme endowed people with 2 ha or less of oil palm plantation, a size well below the recommended cattle stocking rate (in Malaysia) of one head of cattle per four hectares of oil palm plantation (Ab Rahman et al. 2008; Kamil Azmi et al. 2014). The average herd of 4 head of cattle in this study would therefore require 16 ha of oil palm plantation to cover feed requirements, an area unlikely to be met by many smallholders. This issue of land shortage highlights the importance of a good rapport with the surrounding oil palm owners, allowing access to their plantations for cattle grazing.

Although in the study region smallholder farmers were allowed to graze their cattle in the plasma areas, many large-scale plantations are reluctant to have cattle in oil palm plantations because of concerns over stock damage to young trees, soil compaction and overall decrease in oil palm yields (Devendra 2004). These concerns are exacerbated under uncontrolled grazing conditions, which could lead to overgrazing and/or underutilization. Currently, research has not demonstrated positive or negative impacts of cattle grazing in oil palm plantations on soil fertility or oil palm yields, through manure deposition, reduced competition from the understorey, or spread of diseases by cattle (Bremer et al. 2022). Further investigation on this topic could either promote or impede the development of cattle production in oil palm plantations. If outcomes are positive, large-scale plantations might decide to run their own cattle production enterprise on the plantation.

Systematic or targeted grazing (grazing at a particular time, for a specific duration and a set intensity to accomplish vegetation management goals (Frost et al. 2012)) could prevent overgrazing, while allowing synchronisation of cattle grazing with plantation management (e.g. avoiding areas of recent agrochemical application, or promoting the use of recently pruned oil palm fronds as feed). Although not mentioned by the participants, controlled grazing could also ensure estate operations (e.g. harvesting) are not disrupted, while well-timed grazing could potentially decrease plantation weeding costs (Ayob and Kabul 2009; Mohd Azid 2008). Communal cattle management could establish systematic grazing and avoid the 'tragedy of the commons', where the resource is over utilised and degraded because access is not controllable. For this to be possible, transparent and equitable relationships between cattle holders and with plantation owners are necessary (Zen et al. 2006). A communal and systematic grazing system does however present certain barriers for smallholder cattle owners with greater distances between home dwellings and grazing areas resulting in increased management and labour requirements and increased cattle theft concerns.

Compared to fattening, cattle breeding is generally accepted by smallholder farmers as providing longer-term income, savings and asset building

properties, requiring less feed inputs and initial capital (Agus and Widi 2018; Mahendri 2019; Martojo 2012; Rohaeni et al. 2019; Widi 2015). The high proportion of breeders in the study area is in line with the national average of 71% of cattle producing households having breeders (Badan Pusat Statistik 2011). Larger herds in mixed enterprises can be explained by the keeping of calves, breeders and fattened cattle, whereas calves are sold off at weaning in breeding-only enterprises. The adoption of breeding and mixed cattle production enterprises ensures a constant presence of breeders, therefore increasing herd sizes.

Contracting cattle (whether for breeding or fattening) was a 'stepping stone' towards owning cattle for smallholders. It is also generally accepted cattle contracting provides a low-risk entry point to cattle husbandry by avoiding a large financial outlay. Widi et al. (2004), state "Resource-poor farmers can get access to cattle through traditional sharing and formal credit", and Djaelani et al. (2009), explain cattle contracting is an effective means of increasing farmer income and the overall cattle population. The presence of farmer group and government organised cattle contracting schemes is favourable for smallholder cattle production.

Most participants had small herds of Bali cattle. The three participants with Limousin or Brahman cattle obtained these exotic breeds through the governmental contracting schemes, explained by the governmental drive to adopt breeds with higher growth rates and larger carcasses (Agus and Widi 2018; Widi 2015). Bali cattle remained the most prevalent breed, most likely since it is easily sourced, has high fertility, minimal health problems and is adapted to local environmental conditions (e.g. low-quality feed) (Djajanegara and Diwyanto 2001; Lisson et al. 2010; Mahendri 2019; Martojo 2012; Matondang and Talib 2015). Small herd sizes and the prevalence of lower productivity Bali breed (compared to exotic breeds) might be barriers to expanding smallholder cattle production. Currently most research on cattle-oil palm integrated farming systems has concentrated on large estates or experimental plantations with exotic cattle breeds (e.g. Fawzi Hj et al. 1998; Gopinathan 1998; Latif and Mamat 2002; Tohiran et al. 2019). There is presently limited information on the potential productivity of exotic and Bali breed cattle under a smallholder oil palm farming system, information crucial to assessing the productivity and appeal of smallholder integrated farming systems.

The Indonesian transmigration programme has strongly shaped land use patterns in the study region, by defining the onset of farming in the 1980's, the ethnicity of the participants and their demographic profile. As opposed to the indigenous population, the transmigrants were not dependent on forest resources for survival (Rist et al. 2010). Participants' occupation was related to the timing of transmigration: earlier transmigrants were introduced to oil palm and rubber production, whereas later transmigrants fulfilled other full-time occupations (e.g. labourers, merchants). This smallholder profile is explained by the shift in transmigration programme priorities in the early 2000's, with a new category of 'Independent transmigrant' receiving a house and expected to fill labourer shortage in the transmigration towns (Potter 2012). The participants came from islands where the majority of the population is Muslim, which explains why none of the households produced pork. The participants in this study were relatively uniform in their socio-demographic profile, and it is representative of a wider population of transmigrants in Indonesia. Not only are male-headed households typical in Indonesia (83% of Indonesian households are male-headed (Roemling and Qaim 2013)), the transmigration scheme also relocated people to other islands (e.g. Sumatra and Sulawesi), under similar terms and conditions as the ones described in this study (smallholder plasma oil palm farmers, with similar land and work opportunities). Up to 2003, 400,000 settler households (representing 2 million people) were translocated to be part of palm oil nucleus-estate smallholder programmes similar to the one in the study area (Widyatmoko and Dewi 2019).

Conclusion

Smallholder cattle production in oil palm plantations presents a potential opportunity for smallholders given the cultural and economic importance of cattle and the presence of oil palm understorey as a feed resource. Cattle contracting schemes support this integration by providing an entry point for smallholder cattle production, while the presence of breeders is advantageous for ensuring continuous cattle presence and increasing local herd sizes. Uncontrolled

grazing, limited areas of individually owned oil palm plantations, and the understorey being perceived as low-cost feed highlight the issue of 'tragedy of the commons': overgrazing and depletion of the feed resources. Co-operative arrangements to ensure sustainable grazing could be developed to address this issue, simultaneously reducing the risk of cattle theft. These arrangements would however require good rapport between cattle farmers and plantation owners, which, combined with increased labour and travelling distances for grazing could hinder implementation. Currently, large scale oil palm estates are generally reluctant to let cattle graze in their plantation due to concerns over tree damage, soil compaction and yield decreases. To promote smallholder cattle grazing in large scale oil palm plantations, additional information on the impacts of cattle grazing on the oil palm understorey and on oil palm yield is required, which would address the concerns of plantation owners.

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Availability of data and material The dataset generated and analysed during the current study are available from the corresponding author on reasonable request.

Code availability Not Applicable.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article. Author Wahyu Darsono is employed by PT Simbiosis Karya Agroindustri, a subsidiary company of palm oil producing company Buana Karya Bhaki that is considering oil palm—cattle integration.

Ethics approval All activities in this research were approved by the University of New England Human Research Ethics Committee (approval HE19-156). A research permit (342/E5/E5.4/SIP/2019) and visa (VITAS No: 2A1311EB0365-T) were obtained for research in Indonesia.

Consent to participate Written informed consent was obtained prior to the interview.

Consent for publication All participants signed informed consents regarding publishing their data and photographs.

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