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Socio economical evaluation of *Uncaria gambir* cultivation systems in West Sumatra, Indonesia

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ABSTRACT *Uncaria gambir* (Ug) is the main ingredient for producing Gambir which is an international trading commodity that Indonesia has shared its production of 80 % in the world. This paper investigates the type of Ug cultivation system in West Sumatra and its contribution to farmers' income security. Rapid rural appraisal was used for collecting data. Economic analysis is carried out consisting of Benefit and Cost ratio (B/C Ratio), net present value (NPV), internal rate of return (IRR), sensitivity test on the discount rate and Gambir production. Six Ug cultivation systems were found, namely Ug-Mono, Ug-Rubber, and Ug-Areca nut in Lima Puluh Kota regency (LPKR) and in Pesisir Selatan regency (PSR) Ug-Durian, Ug-Durian-Jengkol and Ug-Durian-Petai. In general, The Ug cultivation systems combined with Durian and Jengkol or Petai, that were found valuable additional crops, were more stable in income generation against to the fluctuation of Ug production and Gambir price. Among the six, the highest B/C Ratio was found in Ug-Durian-Jengkol (2.8) while the lowest was in Ug-Mono and Ug-Rubber (1.9). Moreover, Ug-Durian-Jengkol show better NPV and IRR in the most conditions of Gambir price from 10,000 to 100,000 Rp kg⁻¹ as well as Gambir production from 2,400 to 4,800 kg y⁻¹. On the other hand, NPV and IRR of Ug-Mono, -Rubber or -Areca nut systems sharply decreased with the decrease of Gambir price. These systems relied more on Ug production and Gambir price in the income generation. It exhibited the vulnerability of income structure of these systems. From the results, to secure farmers' income from volatility of Ug production and Gambir price, this research suggested Ug cultivation systems combining with durian or other profitable cash crops in West Sumatra.

Key words: BC Ratio, NPV, IRR, Cultivation systems, Gambir, *Uncaria gambir*

INTRODUCTION

Gambir is a dried sap extracted from *Uncaria gambir* (hereafter, Ug) leaves and twigs. This plant has a high concentration of catechin between 7-33 % and tannin between 20-55 % (Zhalimi 2006). Local people use Ug leaves as traditional medicine and Gambir for betel mixture. In pharmaceutical industry, Gambir is used as an ingredient for production of medicine such as antioxidants, and piles used for stress regulation and inflammatory bowel diseases (Anggraini et al. 2011; Chobot et al. 2009; Fan et al. 2017). In the textile industry, Gambir is used for sunlight proof color agent and leather processing (Zhalimi 2006). Currently, developments on the use of Gambir are applied in several other industries such as; the food, beverage and chemical industries (Rauf et al. 2015). Ninety seven percent of Gambir produced in Indonesia is exported to India,

Pakistan, and Bangladesh while the rest is exported to Japan, Malaysia, Singapore, Thailand, Brunei Darussalam, Bahrain and United States. The demand for the Gambir produced has continue to increase yearly with the growth of textile and pharmaceutical industries in India and other importing countries. India alone imported Gambir worth US \$ 32 million with a volume of 14,312 ton from Indonesia in 2012, which shared 99 % of world trade (Directorate General for National Export Development, 2015).

Gambir production consists of two steps, i.e. Ug cultivation-harvest and Gambir production which is the extraction of Gambir composition from the leaves and twigs. The Ug is cultivated by local farmers only, while the extraction is conducted by the Ug cultivating farmers (hereafter, Ug farmers) and sometimes by companies that buy the Ug harvests from local farmers. Indonesia is the largest Gambir producing country and is the worlds' first

Gambir exporter which owns 80 % of world production (Purwanto et al., 2013). The West Sumatra Province is the main Ug cultivation area in Indonesia, which controls 67 % of Indonesia's production. In this province, there are two main areas, Lima Puluh Kota Regency (LPKR) and followed by Pesisir Selatan Regency (PSR). The cultivation field of Ug covers relatively moderate area among all the main cash crops such as palm, rubber, coffee and tea in LPKR and PSR totaling about 39,84 % and 12,44 %, respectively, although Ug field in national average is only 0,19 % in Indonesia (Statistics of Sumatera Barat Province 2015).

For the last ten years, Ug cultivated area have increased by 16 %, about 3,000 ha, with average production of 9,398-ton year⁻¹ while in PSR is has increased by 68 %, about 10,000 ha, with average production only 4,882-ton year⁻¹. The price of Gambir has been fluctuating in the past years as shown in table 1. Ug farmers in West Sumatra are thought to be very prosperous because they monopolize Gambir market supply. However, in reality, Ug farmers are still struggling to find a better option to increase their income due to the unstable price of Gambir. On the Gambir price, farmers can only capitulate on the prices offered by middlemen. This is because the number of buyers are limited in Gambir market and the market structure is an Oligopsony which is the main contributor to the unstable Gambir price (Fauza, 2016). Regardless of unstable prices in the present market, Ug can generate tangible income monthly to the farmer with less input compared to other crops in those regions. Therefore, the local farmers are willing to continue Ug cultivation and to increase their

income.

Besides the effect of the market structure, Ug farmers earn less income due to lack of improved technologies adopted for better Ug cultivation and high quality Gambir to meet export standard (Nasution et al. 2018). Although a pressing machine used for extracting Gambir from Ug leaf and twig is available in the market, most local farmers cannot afford it, thus leading to production of low quality Gambir, as farmers still rely on conventional and less efficient pressing methods. As an alternative approach to increase Ug farmers income, some farmers in PSR have practiced mixed gardening, which combines Ug and other profitable cash crops such as durian (*Durio zibethinus*), jengkol (*Archidendron pauciflorum*) and petai (*Parkia speciosa*). This technique seems a realistic option for farmers to generate additional income from other crops in their Ug fields. Moreover, the vulnerability of Gambir price and its profit that influence farmer income its clearly expose in the study sites. Besides the tradition in producing Gambir has been rooted for generations and it is the main source of income.

However, there is no research analyzing economical structure of the Ug mixed cropping systems. In order to decipher these structures, it is necessary to characterize and evaluate the Ug cultivation systems on its variation and efficiency on income generation. Therefore, the present study examines Ug cultivation systems including Ug monoculture and Ug mixed cropping systems on their variation and income structures and discusses the current movement on Ug mixed cropping systems at the main Ug producing areas in West Sumatra.

Table 1. Cultivated area, Gambir production and price.

Year	LPKR		PSR		Price of Gambir (Rp kg ⁻¹)
	Cultivated area (ha)	Production (ton ha ⁻¹)	Cultivated area (ha)	Production (ton ha ⁻¹)	
2008	14,410	11,790	4,788	3,503	19,265
2009	14,682	14,601	6,314	3,400	27,850
2010	14,577	7,924	7,070	3,102	28,244
2011	15,470	7,743	9,869	5,225	28,244
2012	15,308	7,833	14,714	5,567	28,900
2013	15,424	7,934	15,277	6,005	24,000
2014	15,582	8,722	15,277	5,422	16,000
2015	15,659	8,814	14,314	5,422	20,000
2016	16,199	9,181	14,303	6,794	50,000
2017	17,357	9,444	8,648	4,383	27,000

Rp: **Indonesia Rupiah** (1 USD = 14,400 Rp in June 2018)

Source: Badan Pusat Statistik, 2018

MATERIALS AND METHODS

Study sites

In West Sumatra there are two main Gambir producing regencies which are Lima Pulu Kota Regency (LPKR) and Pesisir Selatan Regency (PSR). These two regencies were selected as representative sites, based on their long history of Ug cultivation and Gambir production (Putri, 2005; Fauza, 2016), at least 100 years according to local farmers. LPKR is located between latitudes $0^{\circ}01'32.6''$ S and $0^{\circ}10'35.4''$ N and longitudes $100^{\circ}15'50.7''$ E and $100^{\circ}50'51.9''$ E (see figure 1), covering a total area of about 335,430 hectares. LPKR is 189 km away from the capital province, Padang, with an altitude of 550–750 meters above sea level (MASL) and average annual rainfall of 1,800–3,700 mm. In LPKR, two villages were chosen, Mahat and Katinggian. PSR is located between latitudes $1^{\circ}03'30.2''$ S and $1^{\circ}16'51.6''$ S and longitudes $100^{\circ}27'18.9''$ E and $100^{\circ}30'16.8''$ E, with a total surface area of 574,988 hectares, and the 62% of this area is covered by protected forest (*Kerinci*

seblat national park). PSR is located 33 km away from the capital province, Padang, and located on the land of 10–115 MASL. In PSR, two villages were chosen, Siguntur tuo and Barungbarung balantai. PSR has an annual rainfall of 1,800–3,700 mm. Both regencies have similar equatorial climate with temperatures between 24 – 32°C (Köppen and Geiger classification). Variations of Ug mixed cropping systems are existing, in which Ug is commonly mixed with one to three horticulture crop species such as areca nut (*Areca cathechu*), rubber (*Hevea brasiliensis*), durian, jengkol and petai. The majority of Ug fields are located on the hillsides, away from local community residence which can only be accessed by foot or use of motorbike.

Data collection on Ug farming system and farmer characteristic

According to FAO, Rapid Rural Appraisal (RRA) is one method that uses for bridging between formal surveys and unstructured research methods such as in-depth

Fig. 1. Study sites: Lima Pulu Kota regency (LPKR) and Pesisir Selatan regency (PSR).

interviews, focus group discussion and observation studies. At LPKR, head of the village and two key informants participated which is from senior Ug farmer and local middleman. At PSR, two key informants participated from village officer and one Ug farmer representative. They were selected purposefully and interviewed based on their knowledge regarding history on Ug and Gambir, development, local demographics, and infrastructure.

Focus group discussion (FGD) is one method of gathering people with similarity in terms of gender, ethnicity, social background, experience, and interest (Nyumba et al., 2018). Focus group discussion targeted collecting information on Ug farmers' cultivation system, types of crops, yield and densities, income estimation and Ug farmers' characteristics by combining questionnaires and in-depth interview. Purposive sampling was used to collect data that related directly to the farmer that applied different Ug cultivation system. Respondents are the representative of majority farmer adopt Ug cultivation systems found in the study sites. Price data were collected from farmers and local middlemen. Data were taken from mid-July to end of September 2017 with 56 farmers at LPKR, and from mid-September to early October 2018 with 15 farmers at PSR. Data and reports obtained from farmers and key informants are reconfirmed to the head of the villages so that the data collected can be accountable.

Data analysis

This study investigated farmer's income generated from Ug cultivation systems along with crops from mixed gardening within Ug fields. Descriptive statistic was used to analyze the Ug cultivation systems, characteristics of different farmers and income structure at the different study sites. Financial analyses were used such as benefit-cost ratio (B/C Ratio), net present value (NPV) and internal rate of return (IRR) to analyze the value between different Ug cultivation systems in these sites. For B/C Ratio (see formula 1) greater than 1 implies the project/investment is profitable and expected to deliver a positive net present value. NPV and IRR are used to determine farmers' investment and cash flow on their Ug and production of other crops using the following formula 2 (Ajijur et al., 2017). According to this financial analysis criteria, when NPV greater than 0 (zero) then it is worth pursuing. IRR is used to estimate profitability of potential projects or investments, calculated by setting up the NPV of all cash flows from the investment equal to zero (formula 3). When the IRR is greater than the discount rate this implies the investment is worth

supporting. By using these three indicators then we could compare all Ug cultivation system differences and justify which system provides best value for the Ug farmer.

$$\text{B/C Ratio} = \frac{\sum_{t=0}^T \frac{B_t}{(1+r)^t}}{\sum_{t=0}^n \frac{C_t}{(1+r)^t}} \quad (1)$$

$$\text{Net Present Value} = \sum_{t=0}^T \frac{B_t - C_t}{(1+r)^t} \quad (2)$$

$$\text{Internal Rate of Return} = \frac{(\text{Cash flow})}{(1+r)^t} - \text{initial investment} \quad (3)$$

Where:

B_t = benefit of production in year t

C_t = cost of production in year t

T = total number of years of production

t = year of production

r = discount rate

To perform B/C Ratio, NPV and IRR it is necessary to give estimation in period of time. In this estimation, all Ug cultivation systems were set within a thirty (30) year time horizon so that data on early and mature stages of Ug and other crops productivity in the Ug field can be generated. Land prices for Ug fields were omitted in the calculations, as all Ug fields were inherited (Dendi et al. 2005), thus the initial investment consists of land preparation and construction of production house. The operational cost, consists of labor costs, weed control and depreciation costs. Depreciation cost is at 10 % based on 30 years of useful life of the first investment therefore it was applied and categorized as a fixed cost. Most farmers in both LPKR and PSR do not apply chemical fertilizers. Therefore, the fertilizer cost is not included in the calculation.

Income calculation was based on the average production of the dried Gambir that farmers sell to middlemen or domestic markets. At LPKR production ranges from 4,680–5,400, with an average of 4,800 kg year⁻¹, while at PSR production ranges between 2,160–2,640 kg year⁻¹ with an average of 2,400 kg year⁻¹. These values, equivalent to 400 and 200 kg month⁻¹ for LPKR and PSR respectively, are different from values reported by provincial statistics which have higher average production of 540 and 288 kg month⁻¹ for LPKR and PSR respectively (Directorate General of Estate Crops, 2013). Crops other than Ug, the yield was calculated with the unit of kg tree⁻¹ year⁻¹. Prices of other cash crops such as rubber, areca nut, durian, jengkol and petai were collected from the market in 2018 while Gambir prices were collected from 2014 to 2018 from farmers and local middleman. Crop yield data from Ug and the other

crops are reported on annual basis. Our preliminary research, indicates no clear relationships between cultivation systems and Ug growth and production.

In order to evaluate the effect of modification of Ug cultivation systems on farmer's income, economical simulations on Gambir production were conducted assuming following conditions: firstly, Gambir production was set at 2,400 kg year⁻¹ which is a condition that farmer might potentially experience at both study sites, secondly, Gambir price was set at (low) 10,000, (medium) 25,000, (medium-high) 50,000 and (high) 100,000 Rp kg⁻¹, thirdly, initial investment were modified corresponding to the crops mixed with Ug and fourthly, interest rate were assumed stable within 30 years of the project for 10 %. Thus, we can analyze which type of cultivation system perform better NPV and IRR after the simulation in both study sites.

RESULTS AND DISCUSSION

Variation of Ug cultivation systems

At LPKR a total 56 Ug farmers were recruited for this study out of these 37 farmers practiced Ug monoculture, 8 farmers adopted a combination of Ug and rubber tree and 11 farmers adopted combination of Ug and areca nut. While at PSR, all 15 Ug farmers recruited adopted a combination of Ug and durian. In addition, out of the 15 farmers, 13 farmers combined Ug durian with jengkol and 1 farmer did with petai (Table 2).

Socioeconomic and Ug farmer characteristics

Table 3 shows the socioeconomic and Ug farmers' characteristics. All of Ug farmers in both regencies were male. At LPKR, farmers between the ages of 41 to 50 years

preferred Ug mixed while farmers less than 40 years preferred to adopt Ug-Mono. Many young and middle-aged Ug farmers in LPKR practice Ug-Mono. This is probably due to the lack of higher educational schools before 2006 in LPKR, as shown in Table 2, seventy-six percent of farmers had not schooled or only finished elementary school while eighty-seven percent of farmers in PSR finished junior or high school. Thus, relatively higher percentage of youth started working after elementary school and resulted in high availability of labor to work in the Ug field in LPKR. Besides, there is an influence from the philosophy of society that someone is said to be a grown up when they are able to producing Gambir. So that producing Gambir becomes a means of supporting life and their main source of livelihood or income in LPKR.

For Ug-Mono, there seems no clear relationships with the number of farmer's dependents while majority of farmers had the number of dependents from 4 to 6 for Ug-mixed. However, we could not find the reason for this in the present study. In terms of the farm size, farmers with Ug-Mono tend to have wider area. Sixty-two percent of the farmers had fields of more than two hectares while only sixteen and twenty percent of Ug-mixed farmers in LPKR and PSR had the field more than two hectares. During the interview, it was found that the farmers of Ug-Mono were motivated to expand their field in order to earn more income, but for Ug-mixed farmers. In PSR, Ug farmers had relatively high level of education, which was due to better school infrastructure and locations close to the provincial capital Padang. It may have facilitated the farmers to make better strategy to get higher income. During the interview at PSR, many farmers raised the reason why they practiced the mixed cropping system was that they could sell the products other than Ug in Padang city markets. This geographical advantage in PSR with higher education was probably the reason why all the farmers in PSR conducted Ug mixed cropping systems.

Table 2. Description on Ug cultivation systems found in study sites.

Site	Farmer	Type of Ug Cultivation Systems	Code
LPKR	37	Uncaria gambir (Ug) monoculture	Ug-Mono
	8	Ug + Rubber (<i>hevea brasiliensis</i>)	Ug-Rubber
	11	Ug + Areca nut (<i>areca cathechu</i>)	Ug-Areca nut
PSR	1	Ug + Durian (<i>durio zibethinus</i>)	Ug-Durian
	13	Ug + Durian + Jengkol (<i>archidendron pauciflorum</i>)	Ug-Durian-Jengkol
	1	Ug + Durian + Petai (<i>parkia speciosa</i>)	Ug-Durian-Petai

Table 3. Socioeconomic and Ug farmer characteristics

No	Characteristics	LPKR n = 56		PSR n = 15
		Ug mono	Ug mixed	Ug mixed
1.	Male	37	19	15
2.	Age			
	10–20 years	4		–
	21–30 years	8	1	2
	31–40 years	24	7	4
	41–50 years	1	11	9
3.	Marital Status			
	Married	32	17	12
	Single	5	2	3
4.	Number of farmer's dependents			
	1–3	11	1	3
	4–6	7	16	10
	>6	12	2	2
5.	Education			
	No education	10	1	–
	Elementary	18	14	2
	Junior High School	7	1	1
	Senior High School	2	3	12
6.	Ug farm size (ha)			
	<2	14	16	12
	2–3.9	9	3	3
	4–5.9	10		–
	>5.9	4		–

Table 4. Income from producing Gambir and from additional crops

Crops	Crop density (crop ha ⁻¹)	Production (kg ha ⁻¹ y ⁻¹)	Price (Rp kg ⁻¹)	Annual TR ^a (10 ³ Rp ha ⁻¹ y ⁻¹)	Labor cost (10 ³ Rp ha ⁻¹ y ⁻¹)	Net Income (10 ³ Rp ha ⁻¹ y ⁻¹)
Gambir LPKR	2,700–3,000	4,800	24,000	115,200	38,400	76,800
Gambir PSR	3,750–4,000	2,400	24,000	57,600	23,040	34,560
Rubber	28	0.2	6,000	33.6	–	33.6
Areca nut	25	50	2,000	2,500	–	2,500
Durian ^b	8	60	40,000	19,200	–	19,200
Jengköl	7	200	12,000	16,800	–	16,800
Petai	3	360	8,000	8,640	–	8,640

Rp: **Indonesia Rupiah** (1 USD = 14,400 Rp in June 2018)

^aTR = Total Revenue = Yield x Price, ^b: Yield and Price are in piece,

Ug farmer income and Ug preference

Table 4 show the estimation of Ug farmer's annual income generated from Gambir and other crops. On Gambir production, LPKR farmers obtained yield twice of that in PSR, in relation to low production at PSR, it is due to the short duration of working time which is around 6–7 hours day⁻¹ while in LPKR on average 10–12 hours day⁻¹. The labor cost was 33.3 % and 40 % of total revenue in LPKR

and PSR, respectively. Labor scarcity at PSR might be one of the reasons why the labor cost was relatively high. Consequently, the net income in LPKR was more than double compared with that in PSR for Gambir. For the additional crops, the crop density in the Ug field was very small compared with that of Ug, especially for durian, jengköl, petai those crumb rubber ratios were less than 1:1250 in the field. Although the crop price was relatively low compared with that of Ug, except Durian (one durian

fruit weighs around 1–1.5 kg). In spite of such small crop density, its' provided better additional income compared to cash crops at LPKR Ug field such as rubber and areca nut. Based on the results of interview with the farmers, since rubber had less appreciated from both demand and price by local middleman compared to Gambir then the farmers began to plant Ug in their rubber fields. Unproductive or old rubber trees were cut down and used as fire wood in the production of Gambir while some productive existing rubber trees in their Ug field were left over aiming to generate additional income from the cram rubber. It is in line with the description of rubber-based agroforestry system or "jungle rubber" in Indonesia specifically Sumatra where jungle rubber is less productive and in order to diverse sources of income then farmer mixed trees or fruit trees in the field (Penot et al., 2017). On the areca nut in LPKR, it was clarified that there was a socio-cultural reason why the local famers cultivated it in spite of its very small income compared with Gambir. Areca nut is used for ceremonies, medicines, land boundary and chewing tradition. Refer to Ug field, farmer plant areca nut functioned as a land boundary. Therefore, farmer can receive benefit from selling it as it has a value in the local market and society or use it for farmer own necessity.

Harvesting of Ug leaves at LPKR is mainly artisanal where farmers have to move from one plant to another throughout the whole field, thus taking up to two month to harvest over an area of one hectare. The leaves and twigs regenerate after two months from time of harvest, thus providing a long harvest period within a year and the possibility of farmers to make more profit. As a result of multiple harvest periods, farmers at LPKR preferred Gambir production, thus moving towards Ug Mono.

At PSR, based on the interview results with both farmers and the head of the village, no Ug farmer carried out Ug-Mono. This was because the farmers were aware of unstable Gambir prices, thus diversifying the crops and getting additional income from harvesting other crops such as durian, jengkol, and petai two to three times a year. Additionally, these Ug farmer (respondents) work on rice fields although the income generated from rice is not reported in this study. This possibly explains the reason why these farmers made less income from Gambir and invested less time in its production process.

Benefit-Cost Ratio (B/C Ratio), Net Present Value (NPV) and Internal Rate of Return (IRR)

Table 5 shows B/C Ratio, NPV and IRR in respective

Ug cultivation systems. The B/C Ratio, NPV and IRR are three related indicators in order to analyze different type of Ug cultivation systems found in the present study. The rule of thumb to this indicator by capturing the value, if $NPV > 1$, or $B/C \text{ Ratio} > 1$ or $IRR > \text{discount rate}$ then the system is worth to pursue (Philipps and Sanghvi 1996).

Initial investment mainly varied in regions. It differed about 10 million Rp between LPKR and PSR. The distance to Ug fields from farmers residence at LPKR were longer compared with those at PSR, resulting in higher transportation costs, thus higher initial cost at LPKR. While in PSR, although labor cost for land preparation slightly more expensive than that in LPKR, it is about 20 % and 11 % respectively. However, the difference did not much influence on the initial investment. In LPKR, 85 % out of the total initial investment goes to construction of production house while 15 % goes to land preparation. In PSR, 68 % out of the total initial investment goes to construction of production house and the remain, 32 %, goes to land preparation.

Operational cost consists of depreciation for the production house, labor, and weed control. It was 39,735,000 Rp in LPKR and 23,927,000 Rp in PSR, the main contributor for higher operational cost was derived from labor cost (96 %), while weed control and depreciation of production house contribute only a smaller amount (4 %) of operational cost. At LPKR, farmers carry out harvests three times a year for that reason the operational costs are higher. In addition, Ug farmer's operational costs start from the second year up to the project period of 30 years.

Farmers started generating income from Gambir when the Ug tree is 18 months old. Ug farmers in LPKR had a higher income from Gambir than those in PSR. Ug farmers in LPKR produced Gambir as much as 4,800 kg year⁻¹ equivalent to Rp 76 million year⁻¹ whereas Ug farmers in PSR only produced Gambir as much as 2,400 kg year⁻¹ equivalent to Rp 34 million year⁻¹. In 6th year to 30th year, the income varied except for Ug Mono because the mixed crops harvest starts from the 6th year. Interestingly, durian, jengkol, and petai generated a significant additional income without increase in labor cost. This was because the farmers harvested these crops themselves and also high prices of these mixed crops. Although rubber and areca nut could also generate additional income without the additional cost in labor, the income was very small, when compared with durian, jengkol, and petai. This might be due to the low prices of rubber and areca nut.

The B/C Ratio indicates that all types of Ug cultivation systems are positive implying these projects gave farmers a large profit margin for 30 years. However, the B/C Ratio was high in order of Ug-Durian-Jengkol, Ug-Durian-Petai,

Table 5. Initial investment, annual cost and benefit, B/C Ratio, NPV and IRR

Description	Year	Type of Ug cultivation system					
		LPKR			PSR		
		Ug-Mono	Ug-Rubber	Ug-Areca nut	Ug-Durian	Ug-Durian-Jengkol	Ug-Durian-Petai
Initial investment for starting cultivation							
Land preparation and construction of production house (10 ³ Rp ha ⁻¹ y ⁻¹)	1	40,500	40,521	40,640	29,192	29,292	29,252
Operational cost:							
Depreciation cost, labor cost and weed control (10 ³ Rp ha ⁻¹ y ⁻¹)	2–30	39,735	39,735	39,735	23,927	23,927	23,927
Total cost (10 ³ Rp ha ⁻¹)		1,153,650	1,153,652	1,153,664	694,779	694,789	694,785
Annual net income (10³ Rp ha⁻¹ y⁻¹)							
Gambir mono	2–5	76,800	76,800	76,800	34,560	34,560	34,560
	6–30	76,800	76,800	76,800	34,560	34,560	34,560
Gambir with Rubber			33.6				
Gambir with Areca nut				2,500			
Gambir with Durian					19,200		
Gambir with Durian and Jengkol						36,000	
Gambir with Durian and Petai							27,840
Cumulative net income for 30 years (10³ Rp ha⁻¹ y⁻¹)							
		2,227,200	2,228,073	2,292,200	1,501,440	1,938,240	1,726,080
B/C Ratio							
		1.9	1.9	2.0	2.2	2.8	2.5
NPV (10 ³ Rp ha ⁻¹ y ⁻¹)		273,999	274,188	289,497	180,703	285,718	234,702
IRR		57 %	57 %	58 %	41 %	49 %	45 %

B/C Ratio: benefit/cost ratio, NPV: net present value, IRR: internal rate of return

Ug-Durian, Ug-Areca nut and Ug-Mono / Ug-Rubber. The higher B/C Ratio of the 3 systems found in PSR was due to low initial investment and operational cost and high contribution from additional crops range from 35 %–52 % for farmer income. Whereas, farmers at LPKR who produced mainly Gambir and generated less than 5 % from additional crops perform better NPV and IRR. IRR is a discount rate that makes the NPV equal to zero. As it showed in Table 6, the sensitivity test of NPV in various discount rates from low of 10 % up to high of 50 % revealed that Ug cultivation systems in LPKR are sustainable at high discount rate (57 %–58 %). It has implication if the discount rate increases up to 50 % then the Ug cultivation systems in PSR will result in negative NPV as it can sustain up to 49 % of discount rate. This implies that Ug cultivation systems in LPKR are more profitable and sustainable.

However, it should be noted that Ug cultivation systems in LPKR require high Gambir production to achieve high NPV and IRR. Beside the fluctuation of

discount rate, factors such as weather, lack of labor and natural disaster which are beyond the capabilities of farmers may affect crop production (Elevitch et al. 2014). From the sensitivity analysis of Gambir production (Table 7), it was found that the Ug cultivation systems in LPKR become less profitable compared to those in PSR as Gambir production is 2,400 kg ha⁻¹ year⁻¹. It is because the NPV in LPKR decrease about 40,000,000 Rp ha⁻¹ y⁻¹ for every decrease in Gambir production by 600 kg from 4,800 kg ha⁻¹ y⁻¹ while in PSR it is only about 25,000,000 Rp ha⁻¹ y⁻¹. This means that Ug farmers in LPKR heavily rely on Gambir's production to increase their income. As discussed above on Table 6 and 7, it was clarified that NPV has strong response to discount rate and production fluctuation of Gambir in LPKR.

In order to discuss profitability and sustainability when different Ug cultivation systems are adopted in these study sites, a simulation was conducted by modifying the Gambir price in both study sites. Results of the simulation are

Table 6. The sensitivity of NPV to the change of discount rate in respective Ug cultivation systems.

Discount rate (r)	NPV (10^3 Rp ha ⁻¹ y ⁻¹)					
	LPKR			PSR		
	Ug mono	Ug-Rubber	Ug-Areca nut	Ug-Durian	Ug-Durian, Jengkol	Ug-Durian, Petai
5 %	492,708	493,083	522,127	350,355	548,935	452,473
10 %	273,999	274,188	289,497	180,703	285,718	234,702
15 %	169,476	169,579	178,611	101,855	164,098	133,857
20 %	112,044	112,103	117,877	60,038	100,092	80,629
25 %	76,856	76,890	80,798	35,431	62,772	49,484
30 %	53,464	53,482	56,237	19,758	39,243	29,770
35 %	36,942	36,950	38,950	9,158	23,502	16,527
40 %	24,730	24,730	26,215	1,652	12,482	7,213

NPV: net present value

Table 7. The sensitivity of NPV to the change of Gambir production in respective Ug cultivation systems.

Gambir production (kg ha ⁻¹ y ⁻¹)	NPV (10^3 Rp ha ⁻¹ y ⁻¹)					
	LPKR			PSR		
	Ug-Mono	Ug-Rubber	Ug-Areca nut	Ug-Durian	Ug-Durian- Jengkol	Ug-Durian- Petai
2,400	110,457	110,645	125,955	180,703	285,718	234,702
3,000	151,342	151,531	166,841	205,234	310,250	259,233
3,600	192,228	192,416	207,726	229,766	334,781	283,765
4,200	233,113	233,302	248,612	254,297	359,312	308,296
4,800	273,999	274,188	289,497	278,828	383,844	332,827

NPV: net present value

shown in Figure 2. In general, NPV of all Ug cultivation systems are positive with the Gambir price higher than 10,000 Rp kg⁻¹ in both study sites and it proportionally increases with the increase of Gambir price. Then IRR, which tells sustainability of the system, also become higher with the increase of Gambir price. Judging from the NPV and IRR values, Ug-Durian-Jengkol, Ug-Durian-Petai and Ug-Durian are found to be better Ug cultivation systems in order to secure farmer's income. These three Ug cultivation systems are capable of providing some profits from the additional crops even though Gambir price become only 10,000 Rp kg⁻¹. The Ug-Durian-Jengkol seems to be the most profitable and sustainable Ug cultivation system in West Sumatra. Lin (2011) stated that mono culture system showed less resilience on future extreme climate change scenario compared to crop diversification or mixed cultivation systems, which also showed a benefit to adopt Ug mixed systems.

Although Ug-Mono or Ug-Rubber or Areca nut systems are less profitable as shown in Figure 2, Ug farmers in LPKR have tried to shift from Ug mixed system to Ug-Mono system recently. It was because they have simply believed

that maximizing Gambir production was the best way to increase their income. In order to extend more profitable Ug cultivation system, ex. Ug-Durian-Jengkol or mixed with other crops, it is necessary to persuade local farmers by providing quantitative economical information as shown in this study and to demonstrate a model cultivation system in LPKR or other Ug mono system area.

CONCLUSION

This study indicates that income generated from Ug cultivation systems varied depending on Gambir production, price and types of crops mixed with Ug. In LPKR, Ug-Mono was the common and some farmers practiced Ug-Rubber and Ug-Areca nut systems while in PSR all the farmers practiced Ug mixed cultivation systems combined with durian and jengkol or petai. Based on the economical analysis referring to the result of NPV and IRR, all Ug cultivation systems in LPKR and PSR are positive and worth to pursue the systems. However, Ug cultivation systems in LPKR looked relied too much on Gambir production,

Fig. 2. Simulation of farmer's income (upper panels for NPV and lower panels for IRR) at different Gambir prices in LPKR (right panels) and PSR(left panels).

which made the farmers income structure less stable against to the fluctuations of Ug production and Gambir price. In order to improve and secure Ug farmer's income, this research suggested Ug farmers, especially Ug Mono farmers, to shift their Ug cultivation systems combined with other profitable cash crops, ex. durian.

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