Soil fertility evaluation and quality of gambier (Uncaria gambir Roxb) in Kundur, Kepulauan Riau

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Abstract. Gambier is the main export commodity of Kepulauan Riau and its quality is highly affected by soil and climate characteristics. The research aim was to study the potency of gambier crop based on the soil fertility evaluation and the quality of gambier products in Kundur, Kepulauan Riau. Study was conducted in Kundur Island, Kepulauan Riau from June to October 2018. The study method was a survey to characterize the land, identify the performance of gambier crop, and collect secondary data and gambier product samples. Results revealed that low to moderate soil fertility of the study area was indicated by low soil pH, total-N, P₂O₅, and K₂O, low to moderate soil organic C and low to very low Ca²⁺, Mg²⁺, K⁺, and CEC, sandy loam to sand clay loam soil texture. Evapotranspiration of productive gambier crop is moderately high causing water deficit in January, February, and March. Based on SNI, catechin content of gambier product from West and North Kundur (52.98 and 50.14%) meet the quality standard 2, while from Kundur (13.19%) does not meet both quality standard 1 and 2. The study areas have a potency for developing gambier crop by providing fertilizer and ameliorant, and applying technology of water supplement.

1. Introduction
Kepulauan Riau Province is one of the production centers for gambier (Uncaria gambir Roxb) in Indonesia. The main producing area for gambier in this province is located at Kundur Island, Karimun Regency. According to BPS Karimun Regency [1], gambier production in this area reached 343.6 tonnes from an area of 303 ha.

Gambier is one of Indonesia's agricultural export commodities with exports value in 2017, 2018, and 2019 were 15,446 tonnes, 15,215 tonnes, and 18,015 tonnes, respectively [2]. India is the largest gambier importer country, which is around 96.88% of the total gambier exports. Other importing countries are Pakistan, Singapore, China, Vietnam, Bangladesh, Japan, Nepal, UAE, and Malaysia [3]. The Ministry of Trade [4] reports that even though Indonesia is the world's leading exporter of gambier, the volume and value of Indonesian gambier exports have fluctuated and not all gambier exports to destination countries show stable conditions and good growth trend every year. This condition is caused by the low quality of gambier products that affects on market price [4]. Meanwhile, the export destination countries have a standard quality of gambier products that could be accepted in the world trade market [5].

Another major problem in gambier cultivation is low productivity. The productivity of the farmer's gambier plants ranges from 300 to 450 kg ha⁻¹, whereas the potential yield of dried gambier can reach
2,100 kg ha\(^{-1}\) [6]. According to the National Standard Agency [7], the chemical properties of gambier greatly determine the quality of gambier products, as stated in the Indonesian National Standard (SNI) 01-3391-2000.

The extract from the dried gambier leaf sap is a product of gambier and is known in the world trade as gambier, cutch, catechu, and pale catechu. The compounds contained in the sap extract of gambier leaves have various potential uses, including cosmetics, medicine, beverages, and paint [8-10]. Gambier chemical compounds include polyphenols such as alkaloid compounds, terpenes, flavonoids, quercetin, and other polyphenolic compounds. There are at least eight forms of gambier appearance, namely coin, areca nut, lumping, biscuit, brown cube, black cube [11].

Understanding of climatic and land characteristics is very important to meet the requirement of gambier crops. These characteristics will determine the gambier product quality. According to Sasmita and Tjahjana [12] the production of the gambier plant is greatly influenced by climates such as rainfall and temperature, and soil physical and chemical properties such as texture, pH, nutrient availability, organic-C, and CEC.

Leaves are the main part of the gambier plant that are processed into the gambier products [13,14]. Jasta and Atman [11] reported that farmers generally harvest leaves twice a year depending on the plant growth stage and the age of the leaves. The harvesting can be done three times a year when the growth is good and the leaves meet the requirements to be harvested. The aging of gambier leaves affects the yield and content of catechin since there is a tendency that younger leaves have a higher yield and catechin content.

The research aim was to study the potency for the development of gambier crop based on the soil fertility evaluation and the quality of gambier (Uncaria gambir Roxb) products in Kundur, Kepulauan Riau.

2. Materials and methods
The study was conducted at the gambier production center in the Kundur Island area, Karimun Regency, Kepulauan Riau from June to October 2018. Karimun Regency is located on 00°24’36”-01°13’12”N and 103°13’12”-104°00’36”E. The study method was a survey to characterize the land, identify the performance of gambier crop, collect secondary data and gambier product samples. The field survey was conducted in 2-3 gambier farms in Kundur, West Kundur, and North Kundur.

The survey activities were carried out in three main gambier producing areas on Kundur Island, Karimun Regency, namely in Kundur, West Kundur, and North Kundur Subdistrict. Activities in the field included slope and altitude identification, and soil sampling for analyzing soil physical and chemical properties. Soil sampling was carried out in a composite of two depths, namely 0-20 and 20-40 cm. Soil samples were analyzed at the Soil Laboratory of Indonesian Soil Research Institute for determination of pH, C-organic, N, P\(_2\)O\(_5\), K\(_2\)O, exchangeable-cations, CEC, BS, Al\(^{3+}\), H\(^+\), and texture. The soil analysis method used refers to the technical guidelines for water, soil, and plant analysis [15].

Secondary 10-year climate data collected from Karimun District Reports in figures consisted of rainfall (mm), maximum and minimum air temperature (°C), relative humidity (%), wind speed (km day\(^{-1}\)), and sunlight (hour). In addition to descriptive analysis, data on climate elements were also used to estimate water availability for the growth of gambier plants. The results of data analysis are displayed in the form of a water balance graph (figure 1) containing monthly rainfall (P), potential evapotranspiration (ET\(_p\)), and evapotranspiration of the gambier plant (ET\(_c\)). ET\(_p\) calculation used the method of Thornthwaite-Mather:

\[
ET_p=1.6F(10T/I)^a
\]  

where F is the day length factor, T is the average monthly temperature, a is a constant with \(a = 0.675 \times 10^{-4} I^3 - 0.771 \times 10^{-4} I^2 + 0.017921 + 0.49329\) and I is the accumulated heat index in one year \((\sum(T/5)^{1.54}).\)
The water requirement of the gambier plant (ETc) was calculated using the formula [16]:

\[ \text{ET}_c = K_c \times \text{ET}_o \]  

(2)

where \( K_c \) is the crop coefficient for water requirements. Since the \( K_c \) value of the gambier plant was not found yet, it was approached by considering the \( K_c \) of tropical shrubs which have almost similar morphology to gambier, namely climbing crops, woody, two m high, and grown in very humid areas (high humidity). For this reason, the recommended \( K_c \) value for mature pepper and cucumber plants, which is 1.15 [16] was used to predict the water needs of adult gambier plants. Meanwhile, ETo is standard evapotranspiration, calculated by the Penman-Monteith method using the Cropwat 8.0 software [17].

Other activities included visits and discussions with two or three gambier farmers in each sub-district to obtain information of land and crop management, such as cultivation practices, inputs used, conservation measures, harvest, and post-harvest, product market, and problems and constraints faced.

To determine the quality of the gambier product, gambier samples produced by the gambier factory in Kundur, Kepulauan Riau were taken. Furthermore, the physical and chemical quality of the gambier samples were analyzed at the Laboratory of the Indonesian Spice and Medicinal Plants Research Institute. The parameters analyzed were in accordance with the parameters in SNI No. 061-3391-2000 [7], namely color and smell (analyzed by visual methods), and moisture content, ash content, water, and alcohol insoluble content were analyzed using the Gravimetric method, while catechin levels were analyzed using the Spectrophotometry method.

3. Results and discussion

3.1. Soil fertility evaluation

Gambier farming locations of this study are in Kundur, West Kundur, and East Kundur, Kepulauan Riau. The locations are at an altitude of 15.0 to 35.7 m above sea level (asl), with a land slope of less than 3% (table 1). Soil types in Kundur Island are Typic Dystrudepts, Typic Hapludults, and Typic Endoaquepts.

Gambier is a tropical plant that can be cultivated from low land (0-200 m asl) to 1,000 m asl. This plant is found to grow well in tropical areas with a daily temperature range of 20-36°C in areas with high rainfall ranging from 2,000 to 2,600 mm. This plant requires full daily light (table 1). Gambier does not need a special soil type, but the soil rich in humus, well drainage and the pH of 5.5-8 is good for gambier cultivation [18].

Table 1. The locations of several gambier plantations on Kundur Island, Karimun, Kepulauan Riau.

| Study sites          | Coordinates | Elevation (m asl) | Slope (%) | Areas (ha) 2008 | 2013 | 2018 |
|----------------------|-------------|------------------|-----------|----------------|------|------|
| Kundur               | 0° 40’ 36”  | 103° 25’ 27”    | 15.0      | 20             | 8    | 6    |
| West Kundur          | 0° 43’ 8”   | 103° 24’ 57”    | 21.4      | 125            | 169  | 185  |
| North Kundur         | 0° 45’ 45”  | 103° 26’ 42”    | 35.7      | 208            | 140  | 96   |

The results of soil chemical properties analysis (table 2) indicated that the soil fertility of the study areas was low to moderate. The soil properties were acid soil reaction, low organic-C, low total-N, low, P2O5, low to moderate K2O, and very low to low Ca2+, Mg2+, K+, and CEC [12]. The suitable soil texture for gambier cultivation is sandy loam to sandy clay loam. Loam textured soils usually have good drainage properties which are suitable for gambier planting. According to Yusmeiarti et al. in Winardi [19] gambier plants grow well on loose soil (soil with good drainage).

In less fertile soil, gambier cultivation can still be done as practiced by the gambier farmers in production center areas in West Sumatra and other areas. However, as stated by [20], if there is no improvement on soil quality then gambier production will be below the potential yield, as the average
production of gambier in production centers in West Sumatra is only around 400 to 600 kg ha\(^{-1}\) [21]. The potential for productivity improvement is quite high because the results of the study showed that the yield of gambier using high-yielding varieties and good management could reach over 2.0 t ha\(^{-1}\) [20]. Poor soil quality also shortens the harvest period for gambier plants, which is only around 5 to 6 years, while in good quality soils the harvest period for gambier plants can reach 20 to 30 years.

The importance of fertilizer to increase the gambier production in marginal land has been stated by Denian et al. [6] that applying 200 NPK kg ha\(^{-1}\) increased gambier leaf and branch production up to 62-78%. It is also reported that gambier leaf contains 1.53% N, 0.08% P, 0.7% K, 0.24% Ca, and 0.16% Mg. Another research found that applying 200 kg NPK ha\(^{-1}\) improved the growth of stem diameter up to 52%, leaf number up to 62%, number of main branches up to 99%, and secondary branch length up to 47% [6]. Using as much as 200 kg ha\(^{-1}\) NPK 15-15-15 fertilizer increased the yield of wet gambier leaves and twigs by 77.67% per clump [6]. It revealed that application of fertilizers in the right amount is one way to get optimal gambier production, considering that the soil nutrient content is limited and tends to decrease due to continuous crop uptake.

Table 2. Soil chemical properties of smallholder gambier plantation in Kundur Island, Kepulauan Riau.

| Parameter          | Study Sites       |           |           |           |
|--------------------|-------------------|-----------|-----------|-----------|
|                    | Kundur            | West Kundur | North Kundur |
|                    | 0-20 cm | 20-40 cm | 0-20 cm | 20-40 cm | 0-20 cm | 20-40 cm |
| pH H\(_2\)O         | 4.7     | 4.5     | 4.6     | 4.5     | 4.6     | 4.6     |
| pH KCl              | 3.6     | 3.4     | 3.7     | 3.4     | 3.6     | 3.5     |
| Organic-C (%)       | 1.42    | 0.97    | 2.95    | 1.42    | 2.13    | 1.39    |
| N (%)               | 0.11    | 0.08    | 0.20    | 0.11    | 0.15    | 0.11    |
| P\(_2\)O\(_5\) (mg 100 g\(^{-1}\)) | 12.6 | 1.4     | 16.8    | 6.5     | 3.4     | 0.4     |
| K\(_2\)O (mg 100 g\(^{-1}\)) | 27     | 11      | 27      | 20      | 37      | 22      |
| Ca (cmol(+), kg\(^{-1}\)) | 0.23  | 0.12    | 0.24    | 0.12    | 0.21    | 0.09    |
| Mg (cmol(+), kg\(^{-1}\)) | 0.19  | 0.16    | 0.17    | 0.15    | 0.16    | 0.11    |
| K (cmol(+), kg\(^{-1}\)) | 0.03  | 0.01    | 0.03    | 0.02    | 0.04    | 0.02    |
| Na (cmol(+), kg\(^{-1}\)) | 0.03  | 0.06    | 0.01    | 0.05    | 0.01    | 0.01    |
| CEC (cmol(+), kg\(^{-1}\)) | 4.95  | 4.47    | 7.02    | 6.43    | 7.88    | 5.65    |
| BS (%)              | 10      | 8       | 6       | 5       | 5       | 4       |
| Al\(^{3+}\) (cmol(+), kg\(^{-1}\)) | 0.99  | 0.84    | 1.39    | 1.30    | 1.48    | 1.55    |
| H\(^{+}\) (cmol(+), kg\(^{-1}\)) | 0.37  | 0.39    | 0.36    | 0.29    | 0.44    | 0.35    |
| Texture             |          |          |          |          |          |          |
| - Sand (%)          | 80      | 73      | 63      | 60      | 63      | 64      |
| - Silt (%)          | 9       | 12      | 14      | 15      | 8       | 9       |
| - Clay (%)          | 11      | 15      | 23      | 25      | 29      | 27      |

3.2. Climate and water balance

As shown in table 3, on average (10 years), based on the Schmidt–Ferguson climate type, there is no dry month category and monthly rainfall <60 mm in the study area. Almost all the months in a year are wet months (P >100 mm), except for February. All indicators of the climatic characteristics of the wet tropics are found in this area such as mean daily temperature from 22-34°C, very humid category (80% humidity or more), and sunlight (9.18 hours day\(^{-1}\)). Meanwhile, the average wind speed in this area (11.42 km h\(^{-1}\)) is in the moderate category. Using the data on climate elements and Cropwat 8.0 software, monthly standard evapotranspiration (ETo) was obtained (table 3).

Furthermore, based on the amount of ETo which is multiplied with the Kc of the gambier crop, the gambier evapotranspiration (ETg) is obtained, so that a water balance graph can be made to see the potential for rainfall to meet the needs of the ETg (figure 1).
The average monthly P in 10-years in the study area (figure 1) indicates that in the Schmidt-Ferguson climatic classification system, the study area is under climate type A. The A climate is a wet climate area of tropical rainforest, with no dry months (P < 60 mm) with a total annual rainfall of 2,431 mm. Even so, matured gambier which are classified as the plants with high water needs (ETg = 1.15 x ETo) still faced a water deficit, especially in months with monthly rainfall approaching the lower limit of the wet month category (P < 100 mm), namely January, February, and March. In these months the gambier had a water deficit of 42-44 mm month⁻¹. The water balance graph illustrates that it is difficult for the farmers to obtain optimal yield of gambier if they only rely on rainfall as a water source, even though the total annual rainfall in the Karimun area is quite high.

Table 3. Climatic characteristics and standardized evapotranspiration (ETo) in Karimun area, Kepulauan Riau, 2009-2018.

| Month    | *Rainfall | *Min temp | *Max temp | *Humidity | *Wind | *Sun | **Rad | **ETo |
|----------|-----------|-----------|-----------|-----------|-------|------|-------|-------|
|          | mm        | °C        | °C        | %         | km day⁻¹ | hours | MJ m² day⁻¹ | Mm day⁻¹ |
| January  | 103       | 23.00     | 33.20     | 81.00     | 17.00  | 7.40  | 20.10  | 4.12   |
| February | 99        | 22.80     | 32.80     | 78.00     | 15.00  | 7.90  | 21.50  | 4.37   |
| March    | 130       | 22.90     | 33.50     | 81.00     | 12.00  | 8.90  | 23.50  | 4.80   |
| April    | 261       | 22.40     | 34.00     | 83.00     | 8.00   | 10.50 | 25.30  | 5.15   |
| May      | 183       | 23.20     | 32.60     | 85.00     | 8.00   | 11.30 | 25.20  | 5.03   |
| June     | 182       | 22.10     | 34.00     | 85.00     | 11.00  | 11.30 | 24.30  | 4.86   |
| July     | 181       | 22.60     | 33.20     | 84.00     | 13.00  | 9.00  | 21.40  | 4.31   |
| August   | 275       | 22.60     | 33.40     | 84.00     | 13.00  | 9.30  | 22.90  | 4.65   |
| September| 251       | 22.40     | 33.50     | 83.00     | 12.00  | 10.00 | 24.80  | 5.03   |
| October  | 226       | 22.70     | 33.60     | 83.00     | 9.00   | 9.00  | 23.20  | 4.76   |
| November | 306       | 22.70     | 32.90     | 83.00     | 7.00   | 8.10  | 21.20  | 4.3    |
| December | 235       | 23.00     | 32.20     | 84.00     | 12.00  | 7.50  | 19.90  | 4.02   |
| Average  | 202.67    | 22.70     | 33.24     | 82.83     | 11.42  | 9.18  | 22.78  | 4.62   |

Source: *Statistic Bureau of Karimun District, ** Cropwat calculation result.

Notes: P = precipitation, ETp = potential evapotranspiration, ETg = gambier evapotranspiration.

Figure 1. Water balance graph for general plant growth evapotranspiration (ETp) and gambier crop evapotranspiration (ETg) in Karimun area, Kepulauan Riau.
To make the Karimun area as a target for gambier development, water resources, especially rainfall, must be managed optimally so that the plant water needs are fulfilled throughout the year. The simplest management method is by rainfall harvesting, which can be used as a source of supplement water irrigation for relatively dry months, namely January, February, and March.

3.3. Gambier performance
Gambier farming on Kundur Island, Kepulauan Riau are generally carried out by farmers and entrepreneurs who are also owners of a gambier processing factory. Farmers' plantations are generally cultivated in an intercropping pattern with other crops, such as banana and rubber, while at the entrepreneur site, gambier farming is carried out in a monoculture pattern. The seeds used generally come from farmers' nurseries, and rarely use seeds from cuttings.

The planting distance of gambier is usually 4 to 5 m. The maintenance is in the form of weeding and fertilization. Fertilization at a dose of 200 kg NPK ha⁻¹ is only applied by farmers who have capital. In general, land management is usually semi-intensive, and rarely given the fertilizer, but cleaning up and pruning remain implemented [10]. The biomass residue of gambier leaf processing in the factory is generally returned to the farms, although most of the farmers rarely apply that biomass compost to the land.

Gambier harvesting is mostly carried out by the buyers (entrepreneurs). The farmers usually receive in cash after harvesting. It is due to the buyer wants to harvest gambier in their own way. Moreover, farmers face some obstacles such as the quality of gambier seeds, long period from planting to harvesting, limited arable land, and limited capital.

3.4. Quality of gambier product
Gambier quality is largely determined by the content of catechin, ash content, moisture content, the content of water-insoluble substances, and alcohol. The main determination of the gambier quality is by catechins and catechin acid tannins contents [22]. The catechin content could be measured of 7 to 33% and catechu tannic acid of 20 to 55% [23]. SNI 01-3391-2000 stipulates catechin content as the main determinant of gambier quality.

Based on SNI 01-3391-2000, the catechin content of gambier products from the West Kundur and North Kundur regions only meets the SNI Quality 2 requirements and does not meet the SNI Quality 1, namely the minimum catechin content is 60% (table 4). Other parameters such as color, water content, water insoluble part content, and alcohol are also still below the SNI Quality 1 and Quality 2. It indicates the need for improving the management techniques for gambier cultivation through improving land quality and water availability for the growth and yield of gambier.

| Parameters                          | West Kundur     | Kundur       | North Kundur | SNI Quality 1       | SNI Quality 2       |
|-------------------------------------|-----------------|--------------|--------------|---------------------|---------------------|
| Color                               | Dark brown      | Dark brown   | Brown        | Yellow-yellow       | Brownish yellow-blackish yellow |
| Smell                               | Specific        | Specific     | Specific     | Specific            | Specific            |
| Water content (%)                   | 19.04           | 13.00        | 18.14        | 14                  | 15                  |
| Ash content (%)                     | 2.24            | 3.69         | 2.32         | 5                   | 5                   |
| Cathecin content (%)                | 52.98           | 13.19        | 50.14        | 60                  | 50                  |
| Insoluble material in water (%)     | 13.31           | 22.46        | 19.24        | 7                   | 10                  |
| Insoluble material in alcohol (%)   | 25.98           | 31.50        | 34.99        | 12                  | 15                  |

Improving the land quality can be done by the application of organic and inorganic fertilizers and soil ameliorant. In addition, sufficient plant water availability, especially in months of low rainfall (January, February, and March), can improve the quality of gambier products. The intervention of land
management and supplement irrigation technology innovation combined with the availability of sufficient land is believed to increase opportunities for the development of gambier commodities in the Kepulauan Riau and the study area in particular.

4. Conclusions
The quality of gambier products in Kundur Kepulauan Riau is lower than the SNI’s requirements. The low quality is closely related to the status of soil fertility, water availability, and gambier cultivation practices by the farmers. Low soil fertility status is indicated by low soil pH, organic-C, nutrient content, and CEC, as well as a deficit in water availability occurring in January, February, and March. Gambir cultivation techniques practiced by farmers are still classified as conventional in the seed sources, land management techniques, harvest, and post-harvest.

Improving the quality of gambier products in Kundur area can be done through (i) improving the soil fertility status by applying organic, inorganic, and ameliorant fertilizers; (ii) providing adequate water during water deficit months through rainfall harvesting and water supplement irrigation techniques, and (iii) improving cultivation techniques. These efforts are believed to be able to realize the development of gambier commodities in the Kundur region, Kepulauan Riau.

References
[1] BPS 2018 Kabupaten Karimun Dalam Angka (in Bahasa) (Karimun: Badan Pusat Statistik)
[2] Kementerian Pertanian 2019 Kinerja Kementerian Pertanian Tahun 2018 (in Bahasa) (Jakarta: Kementerian Pertanian)
[3] Dhalimi A 2006 Permasalahan gambir (Uncaria gambir L.) di Sumatera Barat dan alternatif pemecahannya (in Bahasa) Perspektif 5(1) 46–59
[4] Kementerian Perdagangan 2017 Peluang Ekspor Gambir dan Biji Pinang (in Bahasa) Warta Ekspor https://docplayer.info/7339618-Gambir-dan-biji-pinang.html
[5] Nazir M 2000 Gambir: Budidaya, Pengolahan dan Prospek Diversifikasinya (in Bahasa) (Padang: Yayasan Hutanku)
[6] Denian A, Taher S, Ruhnayat A and Yudarvis 2004 Status teknologi produksi tanaman gambir (in Bahasa) Prosiding Seminar Expose Teknologi Gambir Kayumanis dan Atsiri Balai Penelitian Tanaman Rempah dan Obat Pusat Penelitian dan Pengembangan Perkebunan pp 15–29
[7] BSN 2000 Standar Nasional Indonesia 01-3391-2000 (in Bahasa) (Jakarta: BSN)
[8] Labanni A, Zulhadjri, Handayani D and Arief S 2018 Uncaria gambir Roxb mediated green synthesis of silver nanoparticles using diethanolamine as capping agent IOP Conference Series: Materials Science and Engineering 1 1–6
[9] Rauf A, Rahmawaty, and Siregar A Z 2015 The Condition of Uncaria gambir Roxb as one of important medicinal plants in North Sumatra Indonesia Procedia Chem. 14 3–10 http://dx.doi.org/10.1016/j.proche.2015.03.002
[10] Zebua EA, Silalahi J, and Julianti E 2018 Hypoglycemic activity of gambier (Uncaria gambir Roxb) drinks in alloxan-induced mice IOP Conference Series: Earth and Environmental Science 122 1–8
[11] Jastra Y dan Atman 2016 Produksi Gambir (in Bahasa) (Yogyakarta: Plantaxia)
[12] Sasmita K D and Tjahjana B E 2011 Hubungan kandungan hara tanah dan produksi gambir di Sumatera Barat (in Bahasa) Bul RISTRI. 2(3) 353–60
[13] Yunarto N and Aini N 2015 Effect of purified gambir leaves extract to prevent atherosclerosis in rats Health Science Journal of Indonesia 6 105–10
[14] Andasuryani, Purwanto Y A, Budiastra I W and Syamsu K 2014 Prediction of catechin content in gambier (Uncaria gambir Roxb) using nir spectroscopy J Teknol Ind Pertan. 24(1) 43–52
[15] Sulaeman, Suparto and Eviati 2005 Analisis Kimia Tanah, Tanaman, Air, dan Pupuk (in Bahasa) eds Prasetyo B, Santoso D and Widowati L (Bogor: Balai Penelitian Tanah) p 136
Allen R G, Pereira L S, Raes D, Smith M 1998 Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56 p 300
https://www.researchgate.net/publication/235704197_Crop_evapotranspiration-Guidelines_for_computing_crop_water_requirements-FAO_Irrigation_and_drainage_paper_56

FAO 2006 CropWat http://www.fao.org/land-water/databases-and-software/cropwat/en/

Tropical The Ferns IN 2020 Useful Tropical Plants In: tropical.theferns.info http://tropical.theferns.info/viewtropical.php?id=Uncaria_gambir

Winardi 2005 Peluang penerapan usahatani konservasi untuk pertanaman gambir di Sumatera Barat (in Bahasa) J Sumberdaya Lahan 5(2) 95–102

Fauza H 2014 Gambier: Indonesia leading commodities in the past Int J Adv Sci Eng Inf Technol. 4(6) 67–72

Atman and Misran 2015 Prospek pengembangan tanaman gambir di Sumatera Barat (in Bahasa) Menguak Potensi Teknologi Spesifik Lokasi Guna Mencapai Kesejahteraan Petani, Teknologi Spesifik Lokasi Penggerak Agribisnis Pedesaan ed Daniel et al. (Bukittinggi: CV. Kristal Multi Media) pp 105–24

Yeni G, Syafruddin D, Kasim A, and Amos 2016 Pengujian kemampuan daya samak cxube dan limbah cair gambir terhadap mutu kulit tersamak (in Bahasa) Jurnal Litbang Industri 6(1) 73–82

Amos I, Zainuddin A, Triputranto, Rusmandana B and Ngudiwaluyo S 2004 Teknologi Pasca Panen Gambir (in Bahasa) (Jakarta: BPPT Press) pp 27–30