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Research Article

# Habitat's Effects on Biomass Content of Gelam (*Melaleuca cajuputi* Maton & Sm. Ex R. Powell subsp. *Cumingiana* (Turcz.) Barlow; Myrtaceae)

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## Abstract
Gelam commonly grows in clumps in peat swamp forests of South and Central Kalimantan. This study aims to determine the effects of growing sites on the biomass content of gelam stands. The study was carried out by analyzing the soil content of growing sites toward the growth of gelam (i.e. the number of individuals and biomass per hectare). The study was conducted at two sites, with the following habitat types: site A – shallow peat with a depth of 51-100cm and only inundated on a high tide, and site B – a moderate peat with a depth of 101-200cm, not flooded but with a groundwater depth of less than 50cm at high tide. A forest fire at site B resulted in higher soil fertility (especially the element K) compared to site A, due to the presence of a pile of ash and charcoal. Also, the fire at site B created more open space, controlled weeds, and at the same time, killed some seedlings and saplings, thinning the site out. The growth rate of gelam at site B was higher than that of site A; at site B, the average height was 10.9m and the average diameter was 10.9cm while at site A, the average height was 9.97m and the average diameter was 10.3cm. The presence of ash, charcoal and more open space after the forest-fire resulted in a higher biomass content at site B (147.223 tons/ha) compared to site A (131.578 tons/ha).

**Keywords**: Biomass, *cajuputi*, peat, Gelam, habitat, Kalimantan

## Introduction
In 1973, intensive use of peatlands for transmigration projects began. In 1995, the Indonesian government executed a massive new rice field programme on peatland in the province of Central Kalimantan, the programme itself was known as the million-hectare Peatland Project (PLG), but it ultimately failed. The land

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from the PLG project became neglected, and gelam grew in the area (Poniman et al., 2006).

Gelam (*Melaleuca cajuputi* Maton & Sm. Ex R. Powell subsp. *Cumingiana* (Turcz.) Barlow) grows predominantly in tidal swamps, and freshwater flooded peatlands (Craven & Barlow, 1997; Colton & Murtagh, 1999; Craven, 1999). Gelam tolerates high acidity, which is found in Kalimantan, especially in Central and South Kalimantan (Craven & Barlow, 1997; Rachmanady et al., 2003). Gelam is frequently found growing in areas with high acidity in freshwater, flooded peatlands (Colton & Murtagh, 1999; Craven, 1999; Supriyati et al., 2015). Gelam is a sub-species of Cajuputi (Craven & Barlow, 1997) with a distribution from mainland Indochina to the western part of Flora Malesiana, with the largest population in Kalimantan. This species also produces essential oil, which is similar to its relative in eastern Indonesia, *M. leucadendra*. In international trade, it is also called cajuput oil with Indonesia and Malaysia being the world's main producers, and the main harvesting area being the island of Borneo (Doran, 1999).

Kinnon et al. (1996) described gelam as a pioneer species ecologically. This was confirmed by Suyanto et al. (2001) who noted that gelam is a fast-growing species. Daryono (2009) and Supriyati et al. (2016) also suggested that gelam can grow in habitats that contain pyrite, with good natural regeneration, especially in shallow and moderate peats with acid sulfate soils. A previous study showed that gelam grows predominantly in the area formerly set aside for the PLG; the species grows in clumps as forest composition of the area (BPDAS Kahayan, 2007). The aim of this study is to determine the effects of growing sites on the biomass content of gelam stands (i.e. number of individuals and biomass per hectare).

## Material and Methods

### *Study area*

The study was conducted in the area of the former PLG (Figure 1) (BPDAS Kahayan 2007). The study area was divided into two sites, (1) site A with shallow peat thickness (51-100cm) located at S 02°50'355'' - S 02°50'520''; E 114°20'383'' - E 114°20'544'', and (2) site B with medium thickness of peat (101-200cm) lying at S 02°49'369'' - S 02°49'627''; E 114°17'462'' - E 114°18'109''. Both sites were selected during a preliminary survey, which found dominant gelam stands and met the parameters of the study plan.

*Data collection*

The study was carried out in several steps, as follows:

Fieldwork: An inventory of total individuals of gelam (seedlings, saplings, poles and trees) at site A and B was made using a one-hectare sampling-plot for each location. The diameter of each specimen and total number of specimens was measured.

Soil Sampling: Soil samples were collected from both sites to determine soil fertility. The samples were collected from three levels of soil depth: 25cm, 75cm and 125cm, and put into a sealed plastic container to maintain their original condition.

Sample selection: Seedlings (four individuals) with height <1.5cm were selected along with saplings (five individuals) with height of > 1.5cm, and diameter of <10cm, poles (five individuals) with a diameter of between 10cm and 20cm, and trees (five individuals) with a diameter of > 20 cm (Soerianegara and Indrawan 2005). A total of 38 samples were selected from both sites (19 each).

Sample collection: Seedlings and saplings were collected by pulling, while poles and trees were laid down first and then pulled out, in other words, samples were collected by a destructive sampling method. Roots, stems, fruit, flowers, branches and leaves, in various stages of growth (seedlings, saplings, poles, and trees) were taken, and weighed to determine the biomass in wet, air-dry, and oven-dry conditions, so that the moisture content and biomass content could be calculated.

*Data analysis*

Soil samples from each site were analyzed using the following parameters: pH ($H_2O$), carbon (%), total N (%), $P_2O_5$ (ppm), K (me/100g), and CEC (me/100g), and followed the procedures provided by Yuwono (2003) and Sulaeman et al. (2009). The biomass was estimated under three conditions (wet, air-dry, and oven-dry), using the allometric equation:

$$Y = a X^{b}$$

Where: Y = biomass; X = diameter at breast height (dbh) for saplings, poles, and trees; while for seedlings as high as 30cm from the ground; a, b = coefficient. The next step was to make an allometric equation model based on the diameter and number of individuals to calculate the biomass content in tons per hectare.

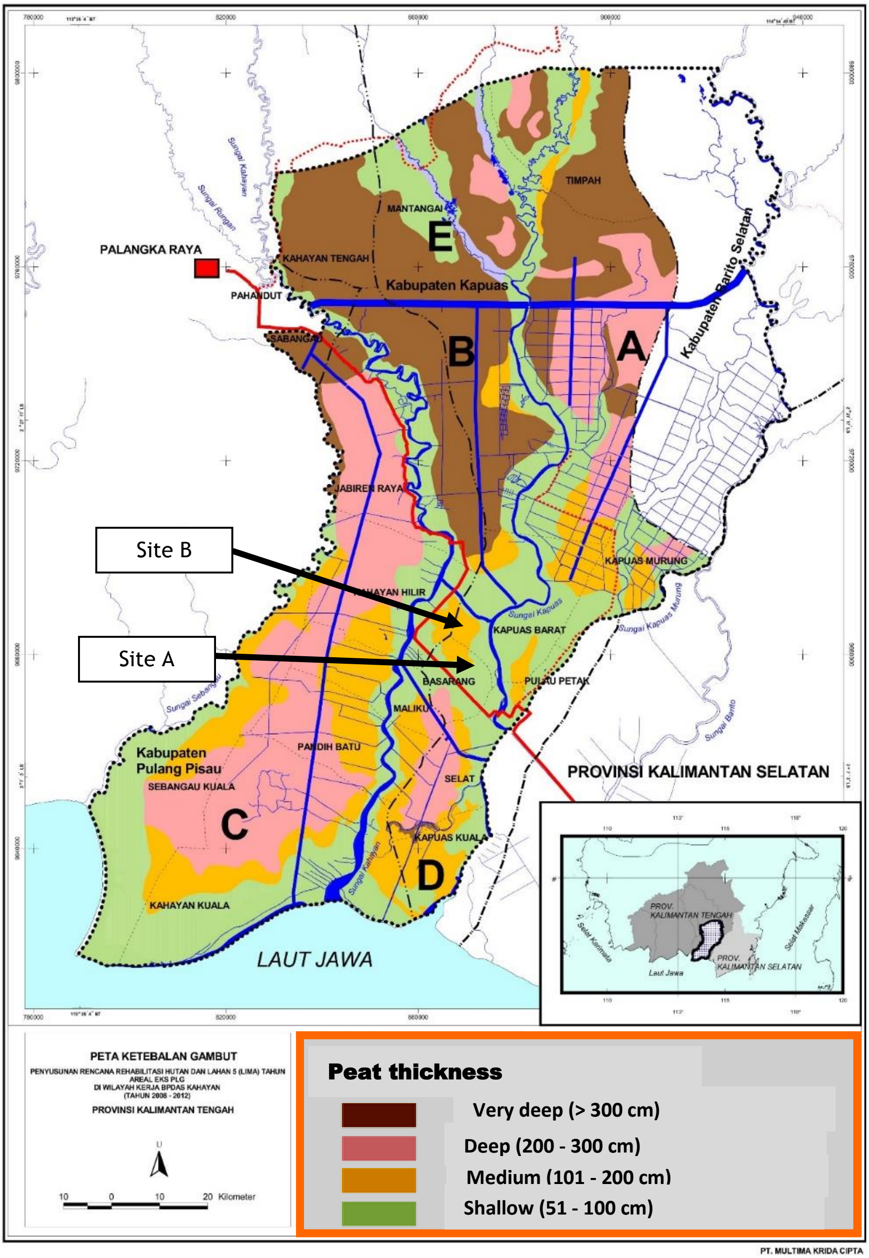


**Figure 1.** Study area

## Results and Discussion

**Table 1.** Total individuals of gelam at different growth stages

| Growth stages | avg. number of individuals per sampling plot | avg. diameter per sampling plot (cm) | total area of sampling plot ($m^2$) | conversion factor to hectare | avg. number of individuals per hectare |
|---|---|---|---|---|---|
| | | | **Site A** | | |
| Seedlings | 144.0 | 0.5 | 100 | 100 | 14,400 |
| Saplings | 442.6 | 4.1 | 625 | 16 | 7,082 |
| Poles | 257.2 | 12.6 | 2,500 | 4 | 1,029 |
| Trees | 65.0 | 23.9 | 10,000 | 1 | 65 |
| Total | - | - | - | - | 22,575 |
| Average | | 10.3 | | | |
| | | | **Site B** | | |
| Seedlings | 239.0 | 0.4 | 100 | 100 | 23,900 |
| Saplings | 114.8 | 6.0 | 625 | 16 | 1,837 |
| Poles | 236.0 | 13.4 | 2,500 | 4 | 944 |
| Trees | 70.0 | 23.7 | 10,000 | 1 | 70 |
| Total | - | - | - | - | 26,751 |
| Average | | 10.9 | | | |

**Table 2.** Parameters of selected samples

| | | | **Site A** | | | | |
|---|---|---|---|---|---|---|---|
| Growth stages | C (cm) | Ø (cm) | H (cm) | C-h (cm) | ØC (cm) | Rd (cm) | ØR (cm) |
| Seedlings | 0.63 | 0.20 | 70.00 | 32.83 | 9.85 | 9.97 | 9.37 |
| | 1.26 | 0.40 | 112.00 | 38.57 | 12.67 | 12.90 | 11.58 |
| | 1.89 | 0.60 | 129.00 | 39.67 | 13.62 | 14.80 | 14.23 |
| | 2.51 | 0.80 | 146.00 | 49.53 | 16.47 | 19.23 | 18.13 |
| Saplings | 4.50 | 1.43 | 288.63 | 134.50 | 59.50 | 42.50 | 65.00 |
| | 9.50 | 3.02 | 715.00 | 250.00 | 100.00 | 40.00 | 80.00 |
| | 13.00 | 4.14 | 872.00 | 300.00 | 150.00 | 55.00 | 90.00 |
| | 19.00 | 6.05 | 1020.00 | 400.00 | 170.00 | 75.00 | 110.00 |
| | 26.00 | 8.28 | 1050.00 | 400.00 | 180.00 | 80.00 | 150.00 |
| Poles | 32.00 | 10.19 | 1071.00 | 406.00 | 238.00 | 85.00 | 180.00 |
| | 38.00 | 12.10 | 1173.00 | 553.00 | 243.00 | 90.00 | 200.00 |
| | 44.00 | 14.01 | 1289.00 | 570.00 | 250.00 | 95.00 | 215.00 |
| | 50.00 | 15.92 | 1341.00 | 575.00 | 332.00 | 98.00 | 240.00 |
| | 56.00 | 17.83 | 1343.00 | 600.00 | 358.00 | 99.00 | 248.00 |
| Trees | 63.00 | 20.05 | 1347.00 | 634.00 | 379.00 | 100.00 | 270.00 |
| | 75.00 | 23.87 | 1490.00 | 800.00 | 386.00 | 115.00 | 275.00 |
| | 83.00 | 26.42 | 1750.00 | 820.00 | 570.00 | 118.00 | 304.00 |
| | 94.00 | 29.92 | 1850.00 | 850.00 | 600.00 | 133.00 | 327.00 |
| | 100.00 | 31.83 | 1880.00 | 800.00 | 600.00 | 139.00 | 353.00 |
| Total | 713.29 | 227.06 | 18,936.63 | 8,253.10 | 4,668.11 | 1,421.40 | 3,160.31 |
| Average | 37.54 | 11.95 | 996.67 | 434.37 | 245.69 | 74.81 | 166.33 |

| Site B | | | | | | | |
|---|---|---|---|---|---|---|---|
| Growth stages | C (cm) | Ø (cm) | H (cm) | C-h (cm) | ØC (cm) | Rd (cm) | ØR (cm) |
| Seedling | 0.63 | 0.20 | 62.00 | 29.08 | 8.07 | 9.05 | 7.97 |
| | 1.26 | 0.40 | 106.00 | 43.33 | 12.17 | 15.50 | 11.83 |
| | 1.89 | 0.60 | 131.00 | 51.30 | 15.37 | 19.33 | 14.52 |
| | 2.51 | 0.80 | 144.00 | 53.67 | 18.90 | 21.73 | 18.90 |
| Poles | 4.50 | 1.43 | 331.75 | 136.00 | 62.00 | 54.00 | 61.25 |
| | 9.50 | 3.02 | 622.00 | 250.00 | 90.00 | 70.00 | 100.00 |
| | 13.00 | 4.14 | 780.00 | 270.00 | 100.00 | 80.00 | 110.00 |
| | 19.00 | 6.05 | 1100.00 | 300.00 | 120.00 | 80.00 | 120.00 |
| | 26.00 | 8.28 | 1190.00 | 350.00 | 155.00 | 80.00 | 130.00 |
| Sapling | 32.00 | 10.19 | 1370.00 | 530.00 | 220.00 | 90.00 | 170.00 |
| | 38.00 | 12.10 | 1430.00 | 550.00 | 250.00 | 90.00 | 200.00 |
| | 44.00 | 14.01 | 1450.00 | 560.00 | 300.00 | 100.00 | 220.00 |
| | 50.00 | 15.92 | 1460.00 | 580.00 | 330.00 | 100.00 | 230.00 |
| | 56.00 | 17.83 | 1620.00 | 660.00 | 340.00 | 110.00 | 235.00 |
| Tree | 63.00 | 20.05 | 1650.00 | 670.00 | 350.00 | 110.00 | 250.00 |
| | 75.00 | 23.87 | 1720.00 | 690.00 | 400.00 | 130.00 | 250.00 |
| | 83.00 | 26.42 | 1740.00 | 720.00 | 430.00 | 135.00 | 260.00 |
| | 94.00 | 29.92 | 1850.00 | 770.00 | 450.00 | 140.00 | 300.00 |
| | 100.00 | 31.83 | 1945.00 | 795.00 | 450.00 | 140.00 | 320.00 |
| Total | 713.29 | 227.06 | 20,701.75 | 8,008,38 | 4,101,51 | 1,574.61 | 3,009.47 |
| Average | 37.54 | 11.95 | 1,089.57 | 421.49 | 215.87 | 82.87 | 158.39 |

Notes: C: Circular; Ø: Diameter at breast height (dbh) for saplings, poles and trees, and 30 cm from ground level for seedlings; H: Height; C-h: Canopy height; ØC: Canopy diameter; Rd: Root depth; ØR: Root diameter.

**Table 3.** Biomass Weight in Wet, Air-dry, and Oven-dry

| Growth stages | dbh (cm) | Site A | | | Site B | | |
|---|---|---|---|---|---|---|---|
| | | W-w (kg/idv) | Ad-w (kg/idv) | Od-w (kg/idv) | W-w (kg/idv) | Ad-w (kg/idv) | Od-w (kg/idv) |
| Seedlings | 0.2 | 0.016 | 0.006 | 0.006 | 0.007 | 0.003 | 0.003 |
| | 0.4 | 0.034 | 0.014 | 0.012 | 0.025 | 0.010 | 0.009 |
| | 0.6 | 0.060 | 0.025 | 0.022 | 0.051 | 0.021 | 0.019 |
| | 0.8 | 0.105 | 0.044 | 0.038 | 0.093 | 0.040 | 0.035 |
| Saplings | 1.4 | 0.892 | 0.394 | 0.346 | 0.980 | 0.462 | 0.406 |
| | 3.0 | 6.250 | 2.830 | 2.482 | 5.600 | 2.834 | 2.475 |
| | 4.1 | 9.930 | 4.814 | 4.218 | 10.890 | 5.738 | 5.010 |
| | 6.1 | 25.210 | 12.294 | 10.733 | 30.660 | 17.407 | 15.045 |
| | 8.3 | 48.980 | 24.332 | 21.174 | 61.920 | 35.408 | 30.562 |
| Poles | 10.2 | 70.940 | 35.373 | 30.764 | 93.060 | 53.321 | 46.189 |
| | 12.1 | 128.900 | 64.351 | 55.723 | 143.670 | 80.886 | 69.956 |
| | 14.0 | 132.110 | 67.899 | 58.889 | 200.360 | 114.428 | 98.955 |
| | 15.9 | 236.590 | 121.735 | 105.351 | 320.040 | 188.334 | 163.257 |
| | 17.8 | 269.450 | 140.188 | 121.212 | 332.460 | 197.840 | 170.199 |
| Trees | 20.0 | 321.160 | 167.995 | 145.955 | 412.710 | 247.882 | 214.562 |
| | 23.9 | 631.350 | 340.959 | 295.821 | 616.080 | 375.923 | 324.977 |
| | 26.4 | 912.950 | 508.988 | 440.388 | 920.180 | 575.799 | 497.731 |
| | 29.9 | 1,116.020 | 620.458 | 539.036 | 1,122.050 | 705.389 | 611.691 |
| | 31.8 | 1,089.760 | 622.972 | 540.138 | 1,265.820 | 825.646 | 708.424 |

Notes: dbh= Diameter at breast height for saplings, poles and trees, and 30 cm from ground level for seedlings; W-w= Wet weight; Ad-w= Air-dry weight; Od-w= Oven-dry weight

Table 1 shows seedlings that grew at site B after the fire were more numerous and younger with a smaller diameter. Table 2 shows that the gelam samples at site B had an average height of 10.9m, an average bole height of 8.22m, and an average diameter of 10.9cm while site A samples had an average height of 9.97m, average bole height of 7.08m, and average diameter of 10.3cm.

**Table 4.** Allometric equations for estimating biomass content

| Correlation between | Sites | Coefficient of determination | Allometric Equations |
|---|---|---|---|
| Diameter at 30 cm from the ground to biomass at seedling stage | A | $R^2$ = 0.979 | $B=0.045Dp^{1.31}$ |
| Diameter at breast height to biomass at sapling, pole, tree growth stages | | $R^2$ = 0.996 | $B=0.153D^{2.36}$ |
| Diameter at 30 cm from the ground to biomass at seedling stage | B | $R^2$ = 0.996 | $B=0.048Dp^{1.76}$ |
| Diameter at breast height to biomass at sapling, pole, tree growth stages | | $R^2$ = 0.999 | $B=0.183D^{2.39}$ |

Notes: Dp= Diameter at 30 cm from ground level for seedlings; D= Diameter at breast height (dbh) for saplings, poles and trees; $R^2$= Coefficient of determination; B= biomass.

The biomass data (oven-dry weight) for each growth stage in Table 3 were used to perform the allometric equation presented in Table 4. Krisnawati et al. (2012) stated that allometric models of biomass estimation – which have commonly been used in Indonesia – are presented in the form of rank functions, namely $Y = aX^b$ where Y is the dependent variable (biomass), X is the independent variable (dbh or a combination of dbh and height), a is the coefficient, and b is the exponent of the allometric model.

**Table 5.** Biomass content at each growth stage

| Growth stages | Biomass ton/ha | Percentage (%) |
|---|---|---|
| | **Site A** | |
| Seedlings | 0.280 | 0.213 |
| Saplings | 49.780 | 37.833 |
| Poles | 63.344 | 48.142 |
| Trees | 18.173 | 13.812 |
| Total | 131.578 | 100.000 |
| | **Site B** | |
| Seedlings | 0.252 | 0.171 |
| Saplings | 31.931 | 21.689 |
| Poles | 89.031 | 60.473 |
| Trees | 26.010 | 17.667 |
| Total | 147.223 | 100.000 |

Allometric equations were applied to the collected data to calculate the biomass content of each stage of growth (seedlings, sapplings, poles and trees) in tons/hectare. The calculation results of biomass content are presented in Table 5, which is the basic data for calculating the total biomass in tons/hectare unit presented in Table 6.

**Table 6.** Total biomass content

| Sites | Biomass ton/ha |
|---|---|
| A | 131.578 |
| B | 147.223 |

**Table 7.** Parameters of soil fertility

| Soil depth (cm) | Sample | pH ($H_2O$) | Carbon (%) | Organic material (%) | N Total (%) | $P_2O_5$ (ppm) | K (me/100 g) | CEC (me/100 g) |
|---|---|---|---|---|---|---|---|---|
| | | | | **Site A** | | | | |
| 25 | 1 | 3.88 | 3.43 | 5.92 | 0.19 | 2.08 | 0.34 | 12.54 |
| 25 | 2 | 3.81 | 3.45 | 5.94 | 0.19 | 2.12 | 0.35 | 11.98 |
| 75 | 1 | 3.81 | 3.16 | 5.45 | 0.21 | 1.99 | 0.37 | 11.71 |
| 75 | 2 | 3.78 | 3.48 | 6.00 | 0.19 | 2.00 | 0.36 | 11.83 |
| 125 | 1 | 3.91 | 4.26 | 7.34 | 0.20 | 2.17 | 0.40 | 8.65 |
| 125 | 2 | 3.80 | 4.25 | 7.33 | 0.20 | 2.17 | 0.37 | 9.00 |
| Average | | 3.83 | 3.67 | 6.33 | 0.20 | 2.09 | 0.37 | 10.95 |
| Criteria * | | Very sour | High | | Low | Low | Medium | Low |
| | | | | **Site B** | | | | |
| 25 | 1 | 3.63 | 3.40 | 5.86 | 0.17 | 1.49 | 0.48 | 9.87 |
| 25 | 2 | 3.75 | 3.20 | 5.52 | 0.16 | 1.57 | 0.48 | 10.01 |
| 75 | 1 | 3.32 | 2.99 | 5.16 | 0.14 | 1.36 | 0.65 | 15.09 |
| 75 | 2 | 3.34 | 2.97 | 5.13 | 0.15 | 1.32 | 0.68 | 14.87 |
| 125 | 1 | 3.40 | 3.80 | 6.70 | 0.16 | 1.59 | 0.57 | 13.25 |
| 125 | 2 | 3.36 | 3.86 | 6.66 | 0.17 | 1.59 | 0.59 | 13.22 |
| Average | | 3.47 | 3.37 | 5.84 | 0.16 | 1.49 | 0.58 | 12.72 |
| Criteria * | | Very sour | High | | Low | Low | High | Low |

Table 6 shows that the total biomass at site B was higher than site A. The result of soil analysis between the two sites are relatively similar based on the parameters of pH, carbon, organic matter, N total, $P_2O_5$, and CEC, while K content at site B was greater than site A (Table 7). A fire at site B resulted in gelam growing well in terms of height and diameter, this is supposedly due to a pile of ash and charcoal formed by the forest fire. Ash contains silicate which had a positive effect on the growth of gelam, especially at site B. This is confirmed by Najiyati et al. (2005) who stated that ash is the residue of burning organic materials such as wood, litter and weeds. Excess ash can increase nutrients, both micro and macro, pH (8.5-10), the soil is not easily leached, and contains base cations such as K, Ca, Mg, and Na which are relatively high. This is evident from a soil analysis that showed site B contained higher K element than site A due to the ash, formed after the fire. This finding is also confirmed by Komarayati et al. (2004) who state that the ash content of litter charcoal is quite high, at 13.7%, which explains why litter charcoal is often used as fertilizer for both perennial and annual crops. Forest fires result in the formation of charcoal from burning biomass which is supposed to fertilize the soil. Gusmailina et al. (2003) explained that charcoal has an important role in fertilizing the soil, including raising the soil pH level, improving soil structure and texture, creating ideal conditions for soil microorganisms, and increasing the CEC. Ogawa (1989) states that charcoal has plenty of pores which can improve water and air circulation in the soil, and in turn expand the root system of plants.

The fires that occurred at site B caused the death of saplings and seedlings and cleared out weeds. This resulted in improved growth of gelam at site B compared to site A. After the fire, the growing area became more open, weeds were absent, and at the same time, a thinning process occurred as some seedlings and saplings had died. Fires do not kill poles and trees, so after the fire there was more growth of the poles and trees due to the increased open space. Trees and poles at site A were not easily burnt due to a high tide that floods the site, keeping the area wet. The growth of gelam at site A was slower due to a denser groundcover, which covered the stand of gelam, such as Kalakai or Lemidi (*Stenochlaena palustris*; Blechnaceae) (Figure 1.), also the dense stand caused the growth of gelam to be slower. This is in line with the study of Nilsen and Strand (2008) which revealed that the spruce, when thinned out gradually from 2070 trees/ha to 1100 trees/hectare, and finally 820 trees/ha could increase the average diameter from 6.4cm (n = 2070), to 6.5cm (n = 1100), and 7.5cm (n = 820), respectively. This is also in line with the results of Susila's study (2010) which revealed that the duabanga (*Duabanga moluccana*; Lythraceae) stand before being thinned out had an average diameter of 20.30cm (n = 508 trees/ha), an average height of 12.64m, and volume of 181.36 $m^3$/ha. After thinning, 172 trees per hectare were left, resulting in an average diameter of 32.88cm, an average height of 19.69m, and a volume of 250 $m^3$/ha.

Forest fires can accelerate the process of peat maturation. The more mature peat will increase soil fertility. This was confirmed by Kurnain (2005) who explained that fires in peatlands could increase the recast of peat material, so that it would quickly mature. Water levels that inundated both sites did not directly affect the growth of gelam, but Yamanoshita et al. (2001), who examined the growth response of *Melaleuca cajuputi* to flooding, found that the higher the water level, the higher the height of *M.cajuputi*.

The aforementioned is the result of analysis and facts in the field of a naturally growing gelam stands. Forest fires certainly cause many losses and must be avoided for forest sustainability. The results of this study suggest gelam can grow well if the habitat is suitable, i.e there is some open space, weeds are controlled and there is fertile soil.

## Conclusions

Forest-fires resulted in better soil fertility and higher levels of the element K. Fires also resulted in more open space, less weeds and at the same time, a thinning process had occurred as some seedlings and saplings had died. There was better growth of gelam at site B compared to site A, and this positively correlated with the biomass content. Forest-fires certainly cause many losses and must be prevented for forest sustainability. However, the results of this study can be a reference that gelam can grow well if the area has some open space, is weed-free and has fertile soil.

## References

**BPDAS Kahayan. 2007.** *Penyusunan rencana rehabilitasi hutan dan lahan lima tahun areal eks PLG di wilayah kerja BPDAS Kahayan (tahun 2008-2012).* Palangkaraya: Laporan Akhir (Final) – BUKU SATU BPDAS KAHAYAN, 107–115.

**Colton RT, Murtagh GJ. 1999.** Cultivation of tea tree. *In*: I. Southwell, R. Lowe (Eds). *Tea tree: The genus Melaleuca*. Amsterdam: Harwood Academic Press, 63–80.

**Craven LA. 1999.** Behind the names: The botany of tea tree, cajuput and nieoli. *In*: I. Southwell, R. Lowe (Eds). *Tea tree: The genus Melaleuca*. Amsterdam: Harwood Academic Press, 11–28.

**Craven LA, Barlow BA. 1997.** New taxa and new combinations in *Melaleuca* (Myrtaceae). *Novon*, **7**:113–119.

**Daryono H. 2009.** Potensi, permasalahan dan kebijakan yang diperlukan dalam pengelolaan hutan dan lahan rawa gambut secara lestari. *Jurnal Analisis Kebijakan Hutan*, **6(2):**71–101.

**Doran JC. 1999.** Cajuput oil. *In*: I. Southwell, R. Lowe (Ed). *Tea tree*: *The genus Melaleuca*. Amsterdam: Harwood Academic Press, 221–236.

**Gusmailina, Pari G, Komarayati S. 2003.** Pengembangan penggunaan arang untuk rehabilitasi lahan. *Buletin Penelitian dan Pengembangan Kehutanan*, **4(10):**21–29.

**Kinnon M, Hatta K, Halim G, Mangalik A. 1996.** *The ecology of Kalimantan (Indonesia Borneo)*. Singapore: Periplus Editions (HK) Ltd.

**Komarayati S, Gusmailina, Pari G. 2002.** *Peranan arang pada proses pembuatan arang kompos*. Bogor: Prosiding Seminar Nasional MAPEKI V.

**Krisnawati H, Adinugroho WC, Imannudin R. 2012.** *Monograf allometric models for estimating tree biomass at various forest ecosystem types in Indonesia*. Bogor: Ministry of Forestry Forestry Research and Development Agency. Research and Development Centre for Conservation and Rehabilitation.

**Kurnain A. 2005.** *Dampak kegiatan pertanian dan kebakaran terhadap biogeokimia lahan gambut ombrogen*. Yogyakarta: Disertasi Universitas Gadjah Mada.

**Najiyati S, Muslihat L, Suryadiputra INN. 2005.** *Panduan pengelolaan lahan gambut untuk pertanian berkelanjutan*. Bogor: Wetlands International - Indonesia Programme.

**Nilsen P, Strand LT. 2008.** Thinning intensity effect on carbon and nitrogen stores and fluxes in a Norway spruce (*Picea abies* (L.) Karst.) stand after 33 years. *Forest Ecology and Management*, **256:**201–208.

**Ogawa M. 1989.** *Mycorhizza and their utilization in forestry*. Samarinda: Report on Short Termed Research Cooperation, the Tropical Rain Forest Research Project, JICA.

**Poniman A, Nurwadjedi, Suwahyuono. 2006.** Penyediaan informasi spasial lahan basah untuk mendukung pembangunan nasional. *Forum Geografi*, **2(2):**130–131.

**Rachmanady D, Lazuardi D, Tampubolon AP. 2003.** *Teknik persemaian dan informasi benih gelam*. Yogyakarta: Pusat Penelitian dan Pengembangan Bioteknologi dan Pemuliaan Tanaman Hutan.

**Soerianegara I, Indrawan A. 2005.** *Ekologi hutan Indonesia*. Bogor: Fakultas Kehutanan, Institut Pertanian Bogor.

**Sulaeman, Suparto, Eviati. 2009.** *Petunjuk teknis analisis kimia tanah, tanaman, air, dan pupuk*. Bogor: Balai Penelitian Tanah, Badan Penelitian dan Pengembangan Pertanian.

**Supriyati W, Prayitno TA, Sumardi, Marsoem SN. 2015.** Kearifan lokal penggunaan kayu gelam dalam tanah rawa gambut di Kalimantan Tengah. *Jurnal Manusia dan Lingkungan*, **22(1):**94–99.

**Supriyati W, Prayitno TA, Sumardi, Marsoem SN, Alpian. 2016.** Local wisdom in utilizing peat swamp soil and water to improve quality of gelam wood. *Tropical Wetland Journal*, **2(2):**27–37.

**Susila IWW. 2010.** Riap tegakan duabanga (*Duabanga moluccana* Bl.) di Rarung. *Jurnal Penelitian Hutan dan Konservasi Alam*, **7(1):**47–58.

**Suyanto S, Applegate G, Tacconi. 2001.** *Community-based fire management, Land tenure and conflict: Insights from Sumatera, Indonesia*. Bogor: Center for International Forestry Research.

**Yuwono NW. 2003.** *Panduan analisis kimia tanah*. Yogyakarta: Fakultas Pertanian, Universitas Gadjah Mada.

**Yamanoshita T, Nuyim T, Masumori M, Tange T, Komija K, Yagi H, Sasaki S. 2001.** Growth respone of *Malaleuca cajuputi* to flooding in a tropical peat swamp. *Journal of Forest Research*, **6(3):**217–219.