IMPACT OF FOREST FIRE INDUCED HAZE ON OIL EXTRACTION RATE (OER) IN CENTRAL KALIMANTAN PROVINCE
Mathews J*, Ardiyanto A

Abstract
Dense haze, caused by the smoke from peat fire in Central Kalimantan, Indonesia from September to October 2015, resulted in low oil extraction rates (OER) in the palm oil mills. The reduced total sunshine hours due to haze affected the OER four weeks after, even though the crop was harvested at the minimum harvesting standard of 5 loose fruits on the ground. The haze resulted in low OER in October and November 2015. Bunch sampling and analysis indicated that the inner fruits were pale yellowish in colour with correspondingly low oil content. The possible emission of ethylene gas from the burning forest and its role in the early abscission of fruits of the fresh fruit bunches (FFB) are discussed in this paper.

1. Introduction
Haze caused by smoke originating from forest and peat fire has become an annual phenomenon in Kalimantan, Indonesia, especially during the prolonged drought months. The smoke is caused by the slash and burn method of land clearing. The last prolonged South East Asia cross border haze from peat fire occurred in 1997/98. In most cases, the victim of the smoke is the Indonesian oil palm plantation industry, which has been alleged to be felling and burning large tracts of forest land for new planting. However, in 2015, the smoke could not be blamed to be caused entirely by oil palm plantations. Many of the large commercial plantations are members of various sustainability groups and they are well aware of their active and transparent policies aimed at a non-burning approach for replanting oil palm. However, some areas within oil palm plantations could have been burnt during the season due to crossover fire from the farmer’s slash and burn activities.

Key words
Abscission, oil extraction rate, haze, forest fire
JOPEH 2016, 7:28-33

*Corresponding Author
Email: Mathews J (joshua.mathews@bumitama.com or joshmathews20@gmail.com)
Ardiyanto A (adhy.ardianto@yahoo.co.id)
Address:
Bumitama Gunajaya Agro Research Centre, Jln Melawai Raya 10, Jakarta 12160, Indonesia
Published: 6 June 2016
Received: 25 April 2016
Accepted: 1 June 2016
© 2016 Mathews J, Ardiyanto A
This is an Open Access article which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.
The practice of slash and burn has now been extended to peat land with disastrous consequences. Severe and dense smoke contributed to the haze that blanketed a wide geographical area covering Singapore, Brunei, Malaysia, and even parts of Philippines and Thailand in 2015. Peat land forest burning is different from the forest fires on mineral soil. The fire smothered into the underground organic matter. These smouldering fires both below and above ground spews prolonged and intense smoke, containing various carbonaceous gases into the atmosphere. Only rain and by raising the water level to its natural condition can the peat fires be doused.

Caliman and Southworth\(^1\) described that the drought and haze in 1997 played a role in the low oil extraction rate (OER) of one of their palm oil mills in Riau, Indonesia. However, they could not provide the reasons for the low OER. Nevertheless, in their study, the negative impact on OER was correlated to global radiation four weeks prior to the crop harvest. They also reported a higher percentage of unripe bunches with low fruit mesocarp oil. During the haze in 2015, there was a general trend towards low OER in palm oil mills.

The present study focused on three palm oil mills located in central Kalimantan where only the crop from within these estates was received and the sunshine hours data was available. Interpretation of data is based on sunshine hours, rainfall, (OER) from the three oil mills and detailed bunch analysis carried out before, during and after the incident. Other possible reasons for the low OER are also discussed in this paper.

2. Materials & Methods

Bumitama Gunajaya Agro’s (BGA) Research Centre is located in Central Kalimantan province and has a weather station. Data on sunshine and rainfall are collected daily. Sunshine hours for the day were measured from Campbell–Stokes Sunshine Recorder (Model Thies). Daily rainfall was measured using a rain gauge.

There were four palm oil mills surrounding the climatological site. However, data of the daily OER were taken for only three of them since they were receiving the company’s own crop, thereby ensuring that the crop quality was within the minimum ripeness standard of 5 loose fruits on the ground before harvesting, with 7 to 9 days intervals between harvesting.

These three mills are located in the western part of Palangka Raya peatland forest, which was the hot spot for the 2015 haze. These mills were situated about 89 km by road from Sampit. During the haze, the wind was towards a westward direction from the hot spot location, so most of the smoke passed through the oil palm plantations surrounding the 3 palm oil mills. In October 2015, there were instances when the visibility was less than 20m. Harvested bunch samples were collected from the base of the trees on a weekly basis. Laboratory bunch analysis was carried out weekly based on the method described by Mathews et al.\(^2\).

3. Observations & Results

The monthly sunshine hours, monthly rainfall (mm) and mean monthly OER of the 3 palm oil mills is shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Daily Sunshine (hours)</td>
<td>6.7</td>
<td>6.6</td>
<td>6.9</td>
<td>6.9</td>
<td>0.9</td>
<td>0.0</td>
<td>5.1</td>
<td>6.3</td>
<td>5.7</td>
</tr>
<tr>
<td>Monthly Rainfall (mm)</td>
<td>299</td>
<td>191</td>
<td>173</td>
<td>39</td>
<td>0</td>
<td>108</td>
<td>334</td>
<td>420</td>
<td>360</td>
</tr>
<tr>
<td>Mean OER of 3 palm oil mills (%)</td>
<td>24.33</td>
<td>24.50</td>
<td>24.92</td>
<td>24.69</td>
<td>24.08</td>
<td>22.25</td>
<td>21.62</td>
<td>23.11</td>
<td>24.04</td>
</tr>
</tbody>
</table>
Recordings of sunshine hours were carried out using Campbell Stoke recorder, which can be affected by clouds and also by dense smoke. Dense smoke is not a daily incident. However, the low sunshine hours in September and October 2015 were due to the forest fire. The low sunshine hours started from 1st of September 2015 until 29th October 2015. Although rainfall resumed on 26th October 2015, the haze lasted until 30th October 2015. The OER in the 3 oil palm mills started declining from 29th September 2015 and dropped to the lowest level on 25th November 2015. The mean OER was 21.62% for this period. Thereafter, there was a slow and steady increment of OER. Correlations of the total sunshine hours with OER are shown in Table 2. The results in Figure 1 show that low sunshine hours resulted in low OER while the results in Table 2 show that the oil extraction at the mills was most affected four weeks after the Indonesian skyline was shrouded with smoke. This period coincided with the presence of the lowest number of sunshine hours as seen in Table 1.

The effect of haze on OER depression is not immediate as observed in Table 2. The correlation between total sunshine hours and one to two weeks before harvesting of crop or extracting the oil in the palm oil mill during the same period were not so strong, with correlation values of 0.59 to 0.68 only. However, the correlation of low total sunshine hours, 3 to 4 weeks before harvesting and OER were highly significant. The maximum effect of low sunshine hours due to haze was observed 4 weeks before harvesting and the highest correlation was observed during this period.

**Figure 1: Relationship of total sunshine hours of four weeks before harvesting**

![Figure 1](image-url)

\[ y = 0.00002x^2 + 0.01083x + 21.61720 \]
Table 2: Correlation of total sunshine hours with weeks before the oil extraction

<table>
<thead>
<tr>
<th>Factors</th>
<th>Correlation value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weekly sunshine hours during the week of mean oil extraction in the oil mill</td>
<td>0.43</td>
<td>Not significant</td>
</tr>
<tr>
<td>Total sunshine hours prior to one week before oil extraction in the oil mill</td>
<td>0.59</td>
<td>Significant</td>
</tr>
<tr>
<td>Total sunshine hours two weeks prior to the oil extraction in the oil mill</td>
<td>0.68</td>
<td>Significant</td>
</tr>
<tr>
<td>Total sunshine hours three weeks prior to the oil extraction in the oil mill</td>
<td>0.88</td>
<td>Highly Significant</td>
</tr>
<tr>
<td>Total sunshine hours four weeks prior to the oil extraction in the oil mill</td>
<td>0.95</td>
<td>Highly Significant</td>
</tr>
<tr>
<td>Total sunshine hours five weeks prior to the oil extraction in the oil mill</td>
<td>0.31</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

The monthly bunch analysis results are shown in Table 3 and these results demonstrate that there was a reduction of oil to bunch in October and November 2015. The main contributing factor for the reduction of oil in the bunch was the low oil content in wet mesocarp, although the bunches harvested were of a much higher standard than the minimum ripeness standard of 5 loose fruits on the ground. The 5 loose fruits on the ground normally correlate to about 10 to 25 loose fruits per bunch after harvesting. However, from the samples collected in October and November 2015, it could be seen that the average loose fruits per bunch were about 59 to 60. In spite of high ripeness standard, the oil to wet mesocarp content was only 42.78% in the month of October 2015 and this increased slightly to 44% in November 2015. This clearly showed that even with higher number of abscised fruits in the fresh fruit bunch, the oil in the wet mesocarp was lower during the haze period.

Table 3: Monthly bunch analysis and compilation of fresh fruit bunch and its components

<table>
<thead>
<tr>
<th>Month</th>
<th>No. of bunches analysed</th>
<th>Loose fruit (no. per bunch)</th>
<th>Bunch weight (Kg)</th>
<th>Fruit to bunch (%)</th>
<th>Wet mesocarp to fruit (%)</th>
<th>Oil to wet mesocarp (%)</th>
<th>Kernel to fruit (%)</th>
<th>Kernel to bunch (%)</th>
<th>Oil to bunch (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug’15</td>
<td>52</td>
<td>66</td>
<td>12.53</td>
<td>59.42</td>
<td>85.81</td>
<td>47.87</td>
<td>5.84</td>
<td>3.60</td>
<td>24.40</td>
</tr>
<tr>
<td>Sep’15</td>
<td>42</td>
<td>53</td>
<td>9.12</td>
<td>56.99</td>
<td>88.14</td>
<td>46.87</td>
<td>5.01</td>
<td>3.03</td>
<td>23.43</td>
</tr>
<tr>
<td>Oct’15</td>
<td>121</td>
<td>60</td>
<td>16.94</td>
<td>66.67</td>
<td>80.40</td>
<td>42.78</td>
<td>8.52</td>
<td>5.73</td>
<td>22.91</td>
</tr>
<tr>
<td>Nov’15</td>
<td>82</td>
<td>59</td>
<td>16.97</td>
<td>64.90</td>
<td>82.19</td>
<td>44.02</td>
<td>8.18</td>
<td>5.38</td>
<td>24.00</td>
</tr>
<tr>
<td>Dec’15</td>
<td>49</td>
<td>40</td>
<td>12.58</td>
<td>62.19</td>
<td>83.24</td>
<td>47.20</td>
<td>7.16</td>
<td>4.50</td>
<td>24.43</td>
</tr>
<tr>
<td>Jan’16</td>
<td>80</td>
<td>43</td>
<td>10.16</td>
<td>65.35</td>
<td>81.09</td>
<td>50.55</td>
<td>7.93</td>
<td>5.26</td>
<td>26.66</td>
</tr>
<tr>
<td>Total/ Mean</td>
<td>426</td>
<td>54</td>
<td>13.91</td>
<td>63.75</td>
<td>82.62</td>
<td>45.93</td>
<td>7.52</td>
<td>4.91</td>
<td>24.08</td>
</tr>
</tbody>
</table>
Detailed visual observations showed that the inner or lower fruits of the spikelets were not ripe and the fruits were generally pale yellowish in colour as shown in Figure 2A. These are unlike the normal ripe fruits which are orange to red in colour as seen in Figure 2B.

Figure 2A: Inner or lower layer fruits are pale yellowish in colour during the haze in October 2015

Figure 2B: Normal inner fruit of adequate ripeness with more orange or red colour.

4. Discussion
Haze induced by forest fire played a role in diminishing the OER, four weeks after its occurrence. The haze in September and October 2015 resulted in low sunshine hours. The correlation of low OER with low sunshine hours was also observed by Caliman and Southworth during the 1997/98 haze season, and they too concluded that the low global radiation 4 weeks before harvesting resulted in low synthesis of oil in the mesocarp and higher percent of unripe bunches. However, they could not explain the reason for such low mesocarp oil synthesis.

Ochs and Daniel reported the possibility of the low oil in the fruits due to a reduction in the photosynthetic process caused by early stomatal closure during the dry season. However, in their description, the percentage of reduction of oil in the mesocarp during the dry season was due to drying up of numerous fruits on the bunch and the seeds from such dried fruits showed significantly lower germination rates than normal seeds. They also indicated in their studies in pot culture that it was impossible for the stomata to close before 11.30 a.m. even if the soil was at the wilting point. So, under haze condition there was a possibility that since the atmospheric concentration of CO$_2$ was high, the intake of a higher volume of CO$_2$ within a short period of time would compensate for the short timing of stomatal opening of leaves. This hypothesis requires further studies. The release of CO$_2$ in a tropical forest and peat tropical forest as a result of burning could vary from 1,563g to 1,643g per kg dry biomass.

In addition to CO$_2$ there would be traces of hydrocarbon gases such as alkanes, alkenes and alkynes, hydrocarbon derivatives and oxygenated volatile organic compounds that could be released into the atmosphere as the result of combustion during a forest fire. One of the hydrocarbons released from the burning of peat in a tropical forest is ethylene, which has the property to effect fruit abscission. This would be the only gaseous plant hormone seen in plants. Burning of tropical forest is considered as one of the largest anthropogenic source of global ethylene emission. The quantity of ethylene emission from a tropical forest fire is about 1.06g, while from peat with above ground tropical vegetation, it is about 1.79g per kg dry biomass. One could imagine that if a peat forest of 200 tons dry biomass per hectare was burnt, it could emit as much as 358 kg per hectare of ethylene. Online news reports assessed that about 300,000 hectares of peat forest were burned in Central Kalimantan in 2015.

The emission of ethylene is at the rate of 0.27g per kg dry straw during the seasonal burning of paddy fields after crop harvest. The highest emission of ethylene is during the smouldering phase of wood, which is about 5g of ethylene per kg dry biomass. The method to induce early and complete abscission of fruits of harvested bunches was reported by Mathews using low concentration of 0.15% of ethrel (2-chloroethyl phosphonic acid), which is a source of ethylene. Volcanic eruption, too releases ethylene. This could have been the reason for low OER during 1991 when Mount
Pinatubo in Philippines erupted. The fumes covered a large area, resulting in low OER for a few weeks\textsuperscript{5,6}. The smoke containing ethylene could have caused the early abscission of the outer fruits, which in turn led to early harvesting of the crop before the fruits on the bunch could fully synthesize the oil content in the fruit mesocarp. This is the reason for pale yellowish fruitlets observed in the spikelet, even though the number of bunches harvested was above the minimum ripeness standard of 5 loose fruits on the ground. The effect of early abscission of fruits was most evident 4 weeks after the atmosphere was shrouded with smoke. Likewise, the increase of OER was seen about 4 weeks after the clearance of the atmosphere from smoke by rain.

5. Conclusions
Haze formed from peat forest fire diminished the OER at the palm oil mill by early abscission of the oil palm fruits before the oil could be fully synthesized in the mesocarp. The amount of oil the fruit was, thus, low with values of 43 to 44\% of oil to wet mesocarp contents during the haze season. The effect of declining oil content was seen 4 weeks after the haze shrouded the atmosphere and could be correlated with the low sunshine hours. The concentration of ethylene in the smoke could have been the reason for the early abscission of the oil palm fruits from the fresh fruit bunch. OER increased 4 weeks after the disappearance of the haze.

6. Acknowledgements
The authors wish to thank P.T. Bumitama Gunajaya Agro (BGA) management for the support to publish the paper. The field and laboratory executives as well as staff who conducted monthly sampling and bunch analysis are gratefully acknowledged.

References
7. Beritasatu.com 2015, Sebanyak 300,000 Ha hutan Terbakar di Kalteng Friday 23\textsuperscript{rd} October 2015.