The impact of revegetation on microclimate in coal mining areas in East Kalimantan.

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Abstract

The study assessed the potential impact of reforestation or revegetation for microclimate as well as the implications of microclimate alteration in a coal mining areas in East Kalimantan. The Measurement of possible microclimate condition was taken at two sites including under forest cover and the nearest open space. Two climate parameters were taken into consideration: solar radiation and temperature. Results showed that the mean daily temperature was lower under forest cover than open space, but with a higher range in the open space . At the same time, difference between maximum and minimum temperature was lower in the under forest cover. Solar radiation was higher in open space than under forest cover; being highly variable between morning and evening in the open space.

Keywords: micro-climate, forest, coal mining, solar radiation, temperature, east kalimantan.

1. Introduction

Forest canopies have enormous importance in the overall functioning of forest ecosystems, and have been the focus of a rapid increase in research activity.(Martin G, et. all. 2001). Microclimate below forest canopies and in forest openings has been studied extensively for decades (Fao 1962; Reifsnyder and Lull 1965; Jarvis et al. 1976; Rauner 1976; Geiger et al. 1995; McCaughey et al. 1997; Chen et al. 1999). Also a number of studies have documented the ability of woodland vegetation to modify its microclimate, particularly the temperature regime within the canopy (e.g. Geiger, 1965; Raynor, 1971; Lee, 1978; Chenet al., 1993; Germino & Smith, 1999; Davies-Colley, 2000; Newmark, 2001; Bonan, 2002).

Microclimate has been defined as the climatic environment of a very local area, such as the north or the south-facing slope of a hill, or an even smaller area. It refers strictly to local combinations of atmospheric factors, which differ from the macroclimate because of uneven topography or differences in plant cover. Within the area of one macroclimate there may exist a whole series of microclimates some of which may differ sufficiently to be of ecological importance. Biologists have frequently pointed out that the climate in which plants and animals actually live is very different from that measured by the meteorologist in a Stephenson screen at 4 ft. 6 in. off the ground; but in the past many studies of plant and animal habitats have relied almost entirely on measurements of the physical factors of the environment obtained from the meteorologist. (Barbara, Coker, 1956)

Variable vegetation thus causes variation in micro-climate across landscape. The main reason is the variation in the ability of different surfaces to distribute the components of the energy balance. Under forest cover, incoming and outgoing radiation is reduced, while the albedo coefficient in evergreen forest with close canopy is always low compared to degraded forest (Stanhill, 1970; Oguntoyinbo, 1970; Geiger et al., 2009). Forest clearing alters this arrangement such that the magnitude of the components of net radiation changes result in greater penetration of solar radiation by day and increased outgoing radiation by night, hence high diurnal range and variability of temperature (Rosenberg, 1974). This is dependent on the size of clearing and proximity to forest stand (Geiger et al., 2009). Thus microclimate of forest edge is different from those of forest floor and clear area farther away from the forest stand.

Mining activities can alter the physical, chemical and biological, a decrease in soil productivity, soil compaction, erosion and sedimentation, landslides occurred movement, disruption of flora and fauna, the disruption of security and population health, and changes in microclimate. Although the succession will occur, that with the change in forest environment will also result in a direct impact on forest vegetation communities, from the primary forest into secondary forest communities, from the secondary forest to plantation society, coupled with the opening of the earth will cause the destruction of the layer structure ground, causing a succession will run very slow compared to the succession that occurs on former farm land or land-logged areas. (Anonymous, 2012)

Mine reclamation is the process of restoring land that has been mined to a natural or economically usable purpose. Although the process of mine reclamation occurs once mining is completed; the preparation and planning of mine reclamation activities occur prior to a mine being permitted or started. Mine reclamation creates useful landscapes that meet a variety of goals ranging from the restoration of productive ecosystems to the creation of industrial and municipal resources. Mine reclamation is a regular part of modern mining practices. Modern mine reclamation minimizes and mitigates the environmental effects of mining. (Anonymous, 2012)

Coal mining in East Kalimantan mining using an open system (open-pit mining system), this system of mining with many negative impacts such as changes in the landscape / relief, loss of ground cover vegetation, drainage patterns and changes and changes in microclimate. Open pit mining system lead to changes in the characteristics of the micro climate of the earth along with the, destruction of soil structure and loss of vegetation and soil cover.

Environmental factors greatly effect on growth and crop production. The influence of environmental factors on life and growth of one or more species of trees studied in terms of autecology. With ecological knowledge (autecology) and physiology is good, to do right actions that silvicultural forest production can be improved in terms of quality and quantity (Soerianegara and Indrawan, 2002).

A. mangium is planted in the Malesian region, especially in Sabah and Peninsular Malaysia, as an ornamental. Significant areas of plantations have been or are being established in India, Indonesia, Malaysia, Papua New Guinea, Sri Lanka and Thailand. About 50,000 ha of *A. mangium* plantations have been established in Sabah and about 42,000 ha in Peninsular Malaysia.

A. mangium is a species of the humid, tropical lowland zones. It tolerates pH levels between 4.5 and 6.5. It occurs behind mangroves in seasonal swamps, along streams and on well-drained flats, low ridges and mountain foothills. *A. mangium* occurs in the Aru Islands, Irian Jaya, Seram, and the Sula Islands of Indonesia; Western Province of Papua New Guinea; and northeastern Queensland, Australia. It is sometimes found dominant in primary and secondary forest, forest margin, savannah, grassland, savanna woodland, on poorly drained floodplains and along fringes of mangrove forest, where it is sometimes associated with *Melaleuca* and *Rhizophora* species. In Papua New Guinea, it often prefers slightly higher and drier sites than other Acacia species growing in the same area. This species has been successfully planted on abandoned areas of shifting cultivation colonized by *Imperata cylindrica* grass, but does not tolerate waterlogging and soils derived from ultrabasic rocks.

A. mangium is employed in soil conservation. Shade or shelter: With its dense foliage, retained throughout the year, A. mangium makes a useful shade tree, screening and soil cover crop. It has been used experimentally in Sabah to shade cocoa. It can also be planted as a wind or firebreak. Nitrogen fixation: *A. mangium* trees form a symbiosis with soil bacteria of the genus Rhizobium, leading to root nodules, in which the bacteria transform free nitrogen into organic and inorganic compounds containing nitrogen. Ornamental: In Malaysia, *A. mangium* is a widely planted roadside tree, and in Thailand, it is recommended for wider use in urban forestry. Intercropping: Experiments have shown that it has potential in some intercropping combinations, such as with maize or peanuts. (Awang, K. 1993)

East Kalimantan is one of the provinces in Indonesia is rich in natural resources such as mineral deposits. The use of land for coal mining is quite large, approximately 2,967,183 hectares. (Anonymous, 2010)

This study aimed to determine the effect of revegetation / reforestation land in the former coal mining area on the micro-climatic conditions, especially temperature and light intensity.

To answer some of the issues above, studies on forest microclimate primarily on plantations revegetation outcomes is needed. This study focused on acacia (*Acacia mangium*. WILD), this was developed extensively in the area of the former coal mine in East Kalimantan province.

2. Material and Methods.

2.1.Study Sites.

The study was conducted during March to September, 2009 in *A.mangium* plantations in coal mining concession area of "Multi Sarana Avindo Coal Mining Company", East Kalimantan, Indonesia. Field surveys in were conducted in *A.mangium* plantation sites with stand ages of 5 years

The area is locate at longitude 117^{O}.04' 42.3" E. and latitude 0^{O}.38'59.3" S. and at elevation 40 – 50 m above sea level (asl), where the annual rainfall is 2,000 mm and annual temperature range between 25^{O}C – 33^{O}C. The soil is a red-yellow podsol and the terrain is flat to undulating. Relative humidity is generally high throughout the year but definitely varies between forested areas and open space. (Ilyas, S, 2012)

2.2.Plot Setting.

One plot 0.625 ha (25 × 25 m) were established to evaluate tree growth characteristics. Stem diameter at breast height (D; 1.3 m above ground) and tree height (H) were measured for all *A.mangium* trees in the plot. D was measured using callipers for trees with small D or a diameter tape for trees with large D. H was measured using an ultrasonic hypsometer for heights > 12 m and a measuring rod for heights < 12 m. One plot 0.625 ha (25 x 25 m) were establish on the open space area.

2.3. Plot Characteristics.

Plot for a micro-climate research in the under forest cover in western disposal revegetation areas, the stands of acacia *(A. mangium*) with a 5 year old with the following conditions: Spacing 3 x 3 m, a maximum diameter 25.14 cm, minimum diameter 5.41 cm. average height clear bole is 6 m, volume is 85.10 m^3ha^{-1} and bassal area is 21.54 m^2ha^{-1}, the average annual increment is 17.02 m^3 $ha^{-1}year^{-1.}$

2.4. Method of Study

Field meteorological instruments used were: Onset Computer Corporation HOBO Pendant® is temperature / light Data Logger 8K - UA-002-08; Supported Measurements: Temperature, Light Intensity, with range **:** Temperature : -20° to 70°C (-4° to 158°F) Light: 0 to 320,000 lux (0 to 30,000 lumens/ft^2), Accuracy **:** Temperature : ± 0.53°C from 0° to 50°C (± 0.95°F from 32° to 122°F), Light intensity: Designed for measurement of relative light levels.

The period for the study was for 13 days. Readings were taken every minute and averages calculated as representing mean daily readings. The data collected were presented in tabular format based on daily means. The data were subjected to both descriptive and inferential statistics. In the former, measures of central tendency (mean and percentages) and measures of dispersion (standard deviation) were used. Inferential statistics involved the use of independent t-test, to determine the level of difference in the sample mean between the different land covers under study.

Air temperatures (◦C) and light intensity were measured at a height of 1.30 m from the ground in the under forest cover and out of the forest under the sun or open space.

3. Results and Discussions

3.1 *Air temperature*

The data generated from the field are as presented in tables 1, 2 and 3. In table 1, it is observed that the mean daily temperature for under forest cover was generally lower than mean daily for open space. On the other hand the mean range also was higher for open space 17.15 °C as against 10.26°C in under forest cover. Besides that the maximum temperature in the open space has reached 43.48°C, in the under forest cover while only reached 36.30 °C .This implies that mean daily temperature was more stable but constantly higher in open space. The generally high range is in conformity with Rosenberg (1974) that whether the surface is bare or vegetated, the greatest diurnal range in temperature is experienced at any level near the surfaces, while the intensity of these changes varies with time. (Francis E. 2012)

However, in terms of the difference between maximum and minimum temperature, the variation was lower under forest cover, implying a more equally daily temperature conditions in this environment. Mean air temperature hourly variation is shown in Fig. 2. At under forest cover, air temperature increases from 06 PM until 02 PM and decreased until 06 PM. Maximum air temperature was 31.31°C, recorded at 01 PM while the minimum was 23.46°C recorded at 06 AM. At open space, maximum air temperature was 35.18°C recorded at 12.30 PM while the minimum was 23.46°C recorded at 06 PM. The open space had higher mean hourly air temperature, recorded higher maximum and lower minimum compared to under forest cover (Fig. 2). This may be due to the protective function of the forest in which during the day incoming solar radiation was being blocked by the vegetative cover while during the night, the vegetative over prevented the energy being radiated out of the atmosphere. (Ahmad, A.N, 1999). Daily variation of air temperature during investigation from March 11 – March 23 shown in Fig. 4.

3.2. Light Intensity

Hourly variation of light intensity is represented in Fig. 3. In open space light intensity increased from 10.80 lux at 6.10 PM and reached maximum of 3,984.98 lux at 12 PM and decreased to 4.89 lux at 6.30 PM

Solar radiation percentage (%)

Forest canopies significantly change the pattern of incoming and outgoing radiation. The forest canopy absorbs much of the incoming solar radiation (insolation). In addition, much of the radiation is reflected – average albedo in a forest is 5–15% , but it can reach nearly 33%. Coniferous forests have albedos of about 8–14%, and values for deciduous woods range between 12 and 18%, increasing as the canopy becomes more open. Consequently, only a small proportion of the sunlight reaches the ground – as small patches of light, known as sunflecks. This is especially so in tropical rain forests where the density of vegetation is high. (Garret Nagle, 2008)

Consequently, temperatures within a forest tend to be lower than outside the forest. However, in a deciduous forest in winter – when the forest has lost its leaves – the temperature within the woodland is likely to be similar to that outside the woodland. For dense beech forests, 80% of the incoming radiation is intercepted by the treetops and less than 5% reaches the forest floor. The greatest trapping occurs in sunny conditions, because when the sky is overcast the more diffuse incoming radiation has greater possibility of penetration laterally to the trunk space. (Garret Nagle, 2008)

The value of solar radiation percentage (%) or 'active solar radiation' absorbed or reflected by the tree (dLight%) was calculated using the following formula: dLight%=100*(Lightsun−Lightsh)/Lightsun. Where Lightsun and Lightsh represent the solar radiation in the sun and shade, respectively. The value of L=100−dLight% gives the percentage of total solar radiation that filters through the foliage—that is, the energy (solar radiation) rate—which is not absorbed or reflected by the tree to the unit surface per sec. and finally manages to 'pass through the tree'. This radiation affects both humans and materials (pavements, grass, asphalt, etc.) that are found in the shade of the tree. (George NJ, Zafiriadis K, 2006) Mean daily solar radiation percentage were presented at table 3.

Solar radiation transmission through forest canopies depends on the height of the crown and the density and arrange-ment of foliage elements (Vézina and Pech 1964; Reifsnyder and Lull 1965; Federer 1971; Black et al. 1991; Canham et al. 1999). Reduction in solar radiation under forest cover ranges from more than 90% with dense canopies (Young and Mitchell 1994; Chen et al. 1995; Brosofske et al. 1997) to 50–70% in open stands (Reifsnyder and Lull 1965; Örlander and Langvall 1993).

The forest canopy changes the spectral distribution of light because plant foliage differentially absorbs and reflects the various wavelengths (Vézina and Boulter 1966; Federer and Tanner 1966; Atzet and Waring 1970; Yang et al. 1993).

4. Conclusion

The potential impact of reforestation on micro-climate in the ex coal mine area as a result of planned plantation reforestation implies.

There is a close relationship between the air temperatures in the open space with the air temperature in under forest cover. Similarly, the close relationship between the light intensity in the open space with in under forest cover. Reforestation should be implemented as it would dissolve the micro-climate which in turn will affect the other ecological elements. With increasing age of the plant, there will be changes in canopy closure, and then there will be changes micro climate. The amount of light reaching the forest floor varies greatly with vegetation type. About 60–75% of the outside light intensity may penetrate to the floor of an *A.mangium* forest. Daily maximum and minimum air temperatures occur near the surface of the ground in openings and in the lower half of the canopy in the forest.

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Table 1. Maximum, minimum and mean temperature (3/11/2009 ~ 3/23/2009)

DAY	DATE	Temperature ^{O}C					
		Under Forest Cover			Open Space		
		Maximum	Minimum	Mean	Maximum	Minimum	Mean
1	3/11/2009	33.01	23.68	26.4	40.76	22.81	27.49
2	3/12/2009	33.22	23.58	26.59	39.50	23.48	27.78
3	3/13/2009	31.88	23.77	26.45	36.73	23.39	27.51
4	3/14/2009	28.56	21.86	24.69	36.62	22.05	25.39
5	3/15/2009	31.47	23.39	26.33	38.05	22.91	27.70
6	3/16/2009	33.54	23.39	27.13	40.65	23.20	29.00
7	3/17/2009	36.30	23.39	26.23	41.58	23.00	26.68
8	3/18/2009	35.86	22.72	26.43	43.48	22.24	27.74
9	3/19/2009	35.22	21.86	26.96	42.52	21.95	28.71
10	3/20/2009	34.06	21.76	26.56	41.23	21.66	28.11
11	3/21/2009	30.56	23.77	26.54	34.80	23.10	27.33
12	3/22/2009	35.33	23.00	25.37	40.88	22.62	25.97
13	3/23/2009	33.22	22.72	26.02	40.88	22.33	27.15
Mean		33.25	22.99	26.28	39.82	22.67	27.43

Table 2. Maximum, minimum and mean light intensity (3/11/2009 ~ 3/23/2009)

Days	Date	Light Intensity (lux)					
		Under Forest Cover			Open Space		
		Maximum	Minimum	Mean	Maximum	Minimum	Mean
1	3/11/2009	2,204.00	8.61	718.41	5,786.70	33.37	2,725.57
2	3/12/2009	2,136.00	16.15	793.44	4,684.48	59.20	2,312.19
3	3/13/2009	1,378.00	5.38	600.90	4,408.92	29.06	2,271.24
4	3/14/2009	1,102.00	8.61	349.74	3,720.02	29.06	1,380.31
5	3/15/2009	1,309.00	23.68	611.26	5,786.70	77.50	2,517.92
6	3/16/2009	2,204.00	21.53	778.01	5,786.70	96.88	2,922.32
7	3/17/2009	2,480.00	27.99	739.26	5,235.59	91.49	1,444.66
8	3/18/2009	2,342.00	26.91	892.02	6,613.38	75.49	2579.89
9	3/19/2009	1,998.00	22.60	928.48	4,960.03	84.41	2,716.00
10	3/20/2009	2,342.00	21.53	877.71	4,684.48	85.04	2,282.66
11	3/21/2009	1,171.00	27.99	631.08	3,720.02	85.17	2,162.11
12	3/22/2009	2,342.00	12.92	602.60	5,786.70	55.00	1,691.35
13	3/23/2009	2,342.00	27.99	743.12	5,235.59	93.65	2,144.13
Mean		1,950.00	19.38	712.77	5,108.41	68.87	2,242.34

Fig. 1. Location of study area in Indonesia.

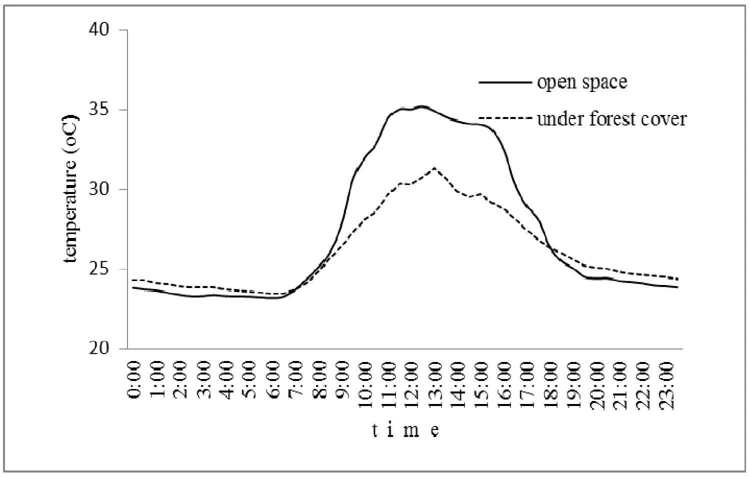

Fig. 2.. Hourly variation of air temperature at open space and under forest cover

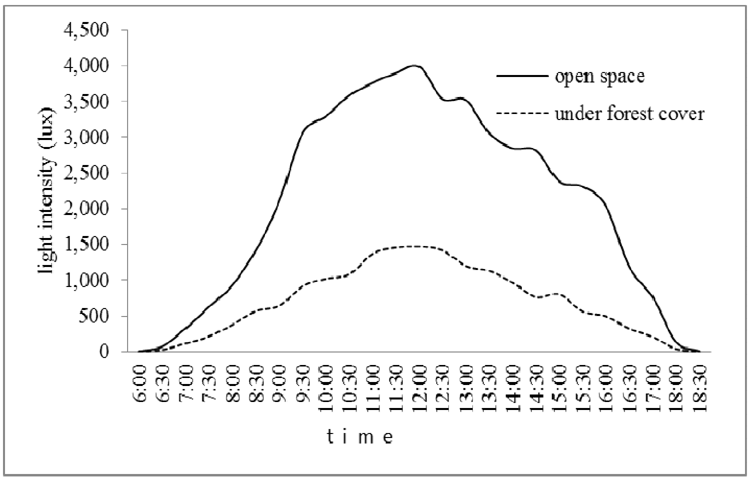

Fig. 3. Hourly variation of light intensity at open space and under forest cover

Table 3. Mean light intensity at open space, under forest cover and percentage of shade.

time	open space (lux)	under forest cover (lux)	(dLight%)	L =100 - (dLight%)
6:10:00 AM	10.80	4.00	62.96	37.04
6:30:00 AM	70.86	24.67	65.18	34.82
7:00:00 AM	325.24	112.36	65.45	34.55
7:30:00 AM	625.30	212.30	66.05	33.95
8:00:00 AM	928.43	374.50	59.66	40.34
8:30:00 AM	1,414.47	565.02	60.05	39.95
9:00:00 AM	2,088.79	637.56	69.48	30.52
9:30:00 AM	3,049.68	910.47	70.15	29.85
10:00:00 AM	3,289.47	1,018.93	69.02	30.98
10:30:00 AM	3,578.27	1,077.55	69.89	30.11
11:00:00 AM	3,757.12	1,365.86	63.65	36.35
11:30:00 AM	3,894.90	1,454.63	62.65	37.35
12:00:00 PM	3,984.98	1,470.52	63.10	36.90
12:30:00 PM	3,534.55	1,414.88	59.97	40.03
1:00:00 PM	3,518.66	1,197.61	65.96	34.04
1:30:00 PM	3,051.00	1,127.40	63.05	36.95
2:00:00 PM	2,844.33	966.02	66.04	33.96
2:30:00 PM	2,813.86	760.10	72.99	27.01
3:00:00 PM	2,377.76	799.76	66.36	33.64
3:30:00 PM	2,309.12	561.55	75.68	24.32
4:00:00 PM	2,035.63	493.74	75.75	24.25
4:30:00 PM	1,181.06	318.53	73.03	26.97
5:00:00 PM	765.07	206.01	73.07	26.93
6:00:00 PM	135.21	36.52	72.99	27.01
6:30:00 PM	4.89	2.00	59.07	40.93
Mean	2,063.58	684.50	66.85	33.15

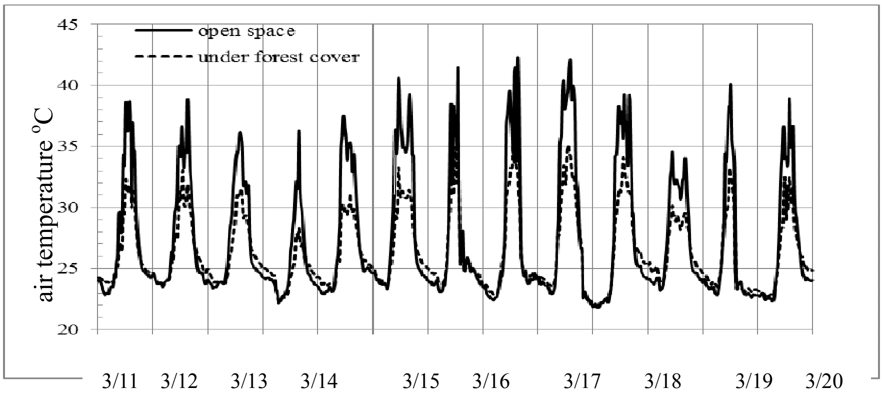

Fig. 4. Daily variation of air temperature during March 11 – March 23, 2009