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## **PAPER F15 - Tree species composition in lowland mixed Dipterocarp forest of Samboja Research Forest three decades after initial major fire**

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### **ABSTRACT**

Tree species composition in lowland mixed Dipterocarp forest of Samboja Research Forest, East Kalimantan significantly changed at three decades after initial major fire of 1983. Permanent plot of 1.8 hectares was observed 2011 by Indonesian Institute of Science collaborate with World Agroforestry Centre to study tree species composition in lowland mixed Dipterocarp forest after affected by repeated fires through record all tree diameter and floristic composition of tree above 10 centimetre DBH in each 10 m x 10 m subplot. Leaves specimen as herbarium were collected during the survey to identify the species. List of species were collected by Indonesian Institute of Sciences before fire of 1981 used as reference. Amount of 192 species recorded in 2011 that consists of 115 pre-fire species and 77 new comer species. Small tree 10-20 centimetre DBH is very common and reach 70% of tree population which is dominated by light demanding species, both of pre-fire and new comer species that considered recruited after second fire of 1998. Even though, number of species is in balance between light demanding and shade tolerant. Only 2.5% of tree population belong to eleven species considered survive from fire. Euphorbiaceae is family with highest number of individual trees up to 25% of total population belong to 10 genera and 25 species which is covered 60% of total genera and species before fire. *Macaranga gigantea* is minor population light demanding pre-fire species develop vastly become dominant species, as well as, *Vernonia arborea* a light demanding new comer species. *Polidocarpus majadun*, *Dipterocarpus cornutus*, *Diospyros borneensis* and *Eusideroxylon zwageri* are pre-fire shade tolerant species consistently co-dominant due to resistant from fire.

**Keywords:** East Kalimantan, forest fire, mixed dipterocarp, species composition, three decades

### **1. INTRODUCTION**

Naturally, fire in tropical rain forest is part of ecological mechanism on maintaining local species richness through succession process that starting with pioneer species; and increasing the complexity over the time to reach the climax community (Eichhorn 2006; van Nieuwstadt 2002; Clements 1916). Fire is important natural forces that has influenced plant communities and serve on maintaining the health of certain ecosystems (Nasi et al. 2001). Wildfires changes plant communities by reducing dominant of some species while enhancing the abundance of others (Pyke et al. 2010).

However, tropical rain forests, particularly in Indonesia which typically do not burn on a large scale due to very dense canopy, wet and humid were devastated by wildfires during the 1980s and 1990s (FAO 2001; Ghazaoul & Sheil 2010). High frequency of forest fire causes tree species loss (Slik et al. 2002), because of direct damage by fire, as well as indirect impact due to

ecological consequences after fire event that effect to regeneration failure (Leighton & Wirawan 1986; van Nieuwstadt & Sheil 2005; Eichhorn 2006; Cochrane & Schultze, 1998; Van Nieuwstadt et al. 2001).

Pioneer tree species regenerate abundantly after fire (van Nieuwstadt 2002; Eichhorn 2006) as gap filling, while survived species continuously growing, but unfavourable species to ecological condition tend to disappeared and caused changing on species composition (Van Nieuwstadt 2002; Slik et al. 2002; Simbolon 2005; Eichhorn 2006; Ghazoul & Sheil 2010). Forest recovery process depends on gap size impacted by fire. Larger gap induced more species migrant rather than species that regenerated from seed bank and re-sprouting from damage tree (Hadley 1986).

Twenty years after initial forest fire in permanent plot of Samboja Research Forest, 60% species richness had recovered, from 254 species in 1.65 hectare area before burnt to 148 species (Simbolon 2005). Furthermore, Simbolon (2005) reported that only 35% pre-fire species regenerated in burnt forest and the other 65% were disappeared, but 60 species of them are recorded as new comer in the area (Simbolon 2005). Also in Samboja Forest research, Krisnawati et al. (2011) registered 14 new comer species recruited in 6 hectares area during 4.3 years and Rahayu et al. (in prep) recorded 42 new comer species in 1.8 hectare during 8 years period of 2003 - 2011.

The composition of major species before burnt and twenty years after, with twice fire event is relatively similar that dominated by *Eusideroxylon zwageri*, *Diospyros borneensis* and *Polidocarpus majadun* (Kartawinata et al. 2008; Simbolon 2005). Sequence plot of unburned, once and twice burnt indicated that burnt area induced by fast growing early-succession species and become species dominant in Sungai Wein during seven years after fire (Slik et al. 2008). Pre-fire species composition is taking a place in burnt forest but in slow progress, up to several decades (Slik et al. 2008).

The objectives of the research is to study tree species composition in lowland mixed Dipterocarp forest of Samboja Research Forest after affected by repeated fires.

## 2. EXPERIMENTAL METHOD

### 2.1 Study site

Research was conducted in Samboja Research Forest where located in Kutai Kertanegara and Penajam Paser District, East Kalimantan, 0°59'23" – 0°59'27" S and 116°57'31" – 116°57'51" E. Permanent plot established by Indonesia Institute of Sciences on 1979 – 1981 for 10.5 hectares area (Figure 1). Revisited plot was done by World Agroforestry Centre and Indonesia Institute of Science on 2011 for 1.8 hectares area.

### 2.2 Methods

Enumeration of all trees more than 10 cm diameter at breast height (DBH) was done in 1.8 hectare area of permanent plot in Samboja Research Forest that divided by 10 m x 10 m sub-plot. Tree DBH, height and position were recorded during the observation. Tree species was identified in Herbarium Bogoriense, Bogor through herbarium collection.

### 2.3 Data analysis

All identified species were grouped taxonomically that covered genus and family level to understand the taxonomic composition and changing during three decades after initial fire. Ecological function group of light demanding 'pioneer' and shade tolerant 'late succession'

species based on published references, as well as tree diameter classes were determined for each individual trees and species to understand current succession stage. Further analysis was done through comparing the current established species to the past three decades species published by Kartawinata et al. (2008) and past a decade species published by Simbolon (2005).



Figure 1: Samboja Research Forest (red dot), East Kalimantan

### 3. RESULT AND DISCUSSION

#### 3.1 Results

During three decades period with twice major fire in 15 years interval, amount of 1075 individual trees above 10 cm DBH belong to 192 species, 101 genus and 41 families recorded in 1.8 hectare area that consist of 115 pre-fire species (found in 1981 survey) and 77 new comer species (not found in 1981 survey). Euphorbiaceae is family with huge number of individual tree (263) belong to 10 genera and 25 species. Survey of 1981 found 16 genera and 45 species in 10.5 hectares (Kartawinata et al. 2008). However, for other 40 families there is no particular relationship between number of genus, species and individual tree (Figure 2).

Myristicaceae, Myrtaceae, Dipterocarpaceae, Lauraceae and Rubiaceae consist of 20, 18, 14, 10 and 10 species, but relatively low number of individual tree in average 2 individual for each species, except for *Diperocarpus cornutus* has 10 individual trees. Moraceae, Annonaceae, Verbenaceae and Areaceae consist of 9, 8, 7, 4 and 3 species with large number of individual tree, but dominated by certain species. Species that contribute high percentage up to 80% of individual tree to the family level are *Artocarpus anysophyllus* (Moraceae) and *P. majadun* (Arecaceae); hence, that contribute about 50% are *Cananga odorata* (Annonaceae) and *Peronema canescens* (Verbenaceae). Rutaceae and Asteraceae consist of single species with large number of individual trees, are *Melicope glabra* and *Vernonia arborea*. The other 23 families contain 2 - 7 genus and species, 1 – 2 individual trees in each species. Alangiaceae, Combretaceae, Elaeocarpaceae, Flacourtiaceae, Monimiaceae and Rosaceae are families that contain single genus, single species and single individual tree in 1.8 hectare area.

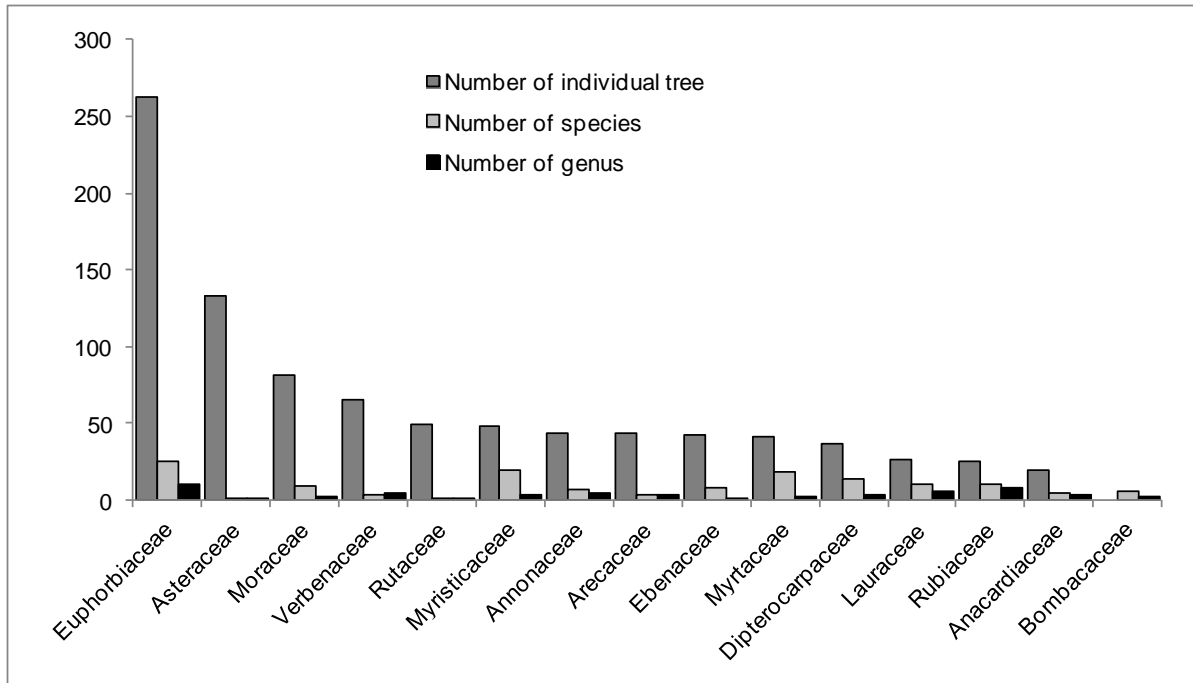


Figure 2: Top fifteen families with highest number of individual trees recorded in 1.8 hectare of permanent plot three decades after initial fire event

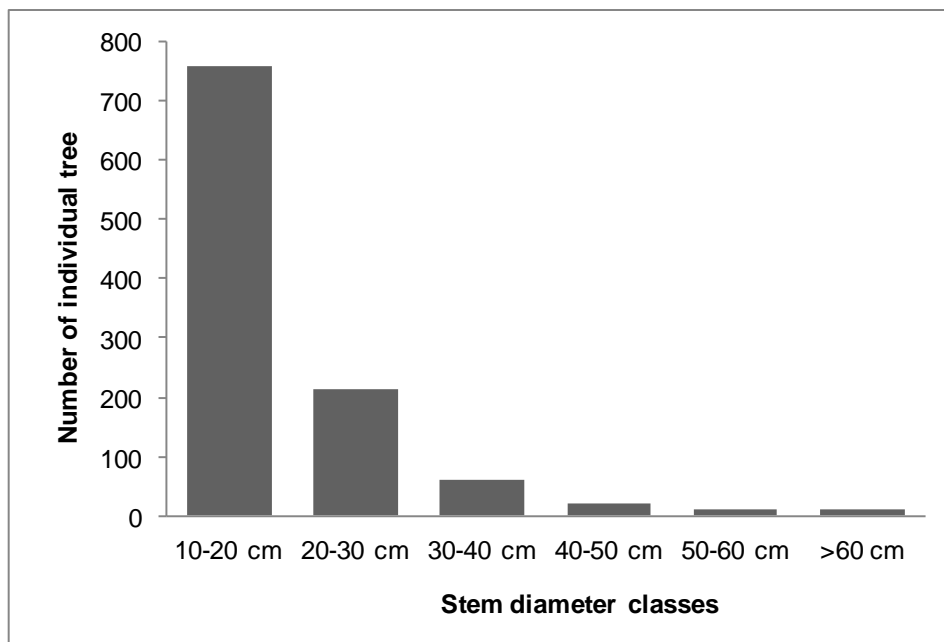


Figure 3: Number of individual tree recorded in 2011 survey based on diameter classes

Compared to 1981 survey, number of species recovered after twice fire in each family is varied, from 5 – 100%, event 200% for Verbenaceae. *P. canescens* and *Vitex pinnata* is new comer species belong to Verbenaceae that considered recruited after fire 1998. Species recovery percentage of major families Myristicaceae, Euphorbiaceae and Dipterocarpaceae is about 60%, but lower percentage at 30% and 20% for Myrtaceae and Lauraceae. Clusiaceae is family with highest number of losing species after fire, from 19 species to one species; followed by Burseraceae, Fagaceae, Sapindaceae, Melastomataceae and Meliaceae that losing about 10 – 15 species.

Three decades after initial fire or thirteen years after second fire, tree diameter composition dominated by small tree, 10 – 20 cm DBH, 70% of total individual trees. The other 20%, 7.5% and 2.5% is 20 – 30 cm, 30 – 50 cm and more than 50 cm DBH, respectively (Figure 3).

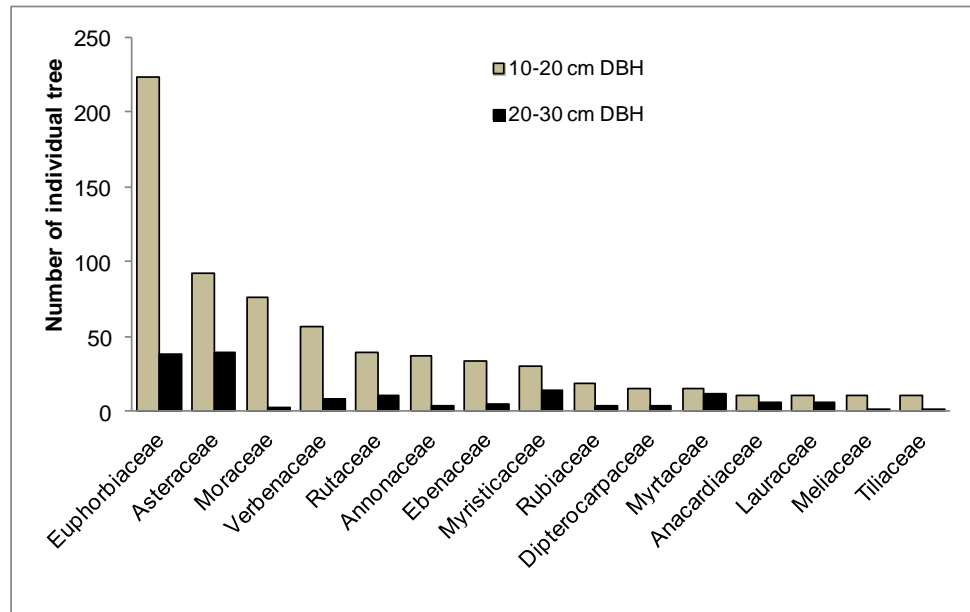


Figure 4: Top fifteen families with highest number of smaller tree 10 – 20 cm and 20 – 30 cm DBH

Huge number of individual tree at 10 – 20 cm DBH regenerated in the burnt forest was contributed by Euphorbiaceae (30%) that 19% of them occupied by *Macaranga gigantea*, Asteraceae with single species of *V. arborea* (12%) and Moraceae that dominated by *A. anisophyllus* (10%) (Figure 4). The other 48% tree population is contributed by 36 families. Half of total individual tree at 20 – 30 cm DBH contributed by Euphorbiaceae (17%) that 12% of them occupied by *M. gigantea*, *V. arborea* of Asteraceae (18%) and *P. majadun* of Arecaceae (15%). The remains of 50% were contributed by 25 families.

Functional ecological group of light response analysis found that number of pre-fire species is in balance, 58 light demanding species and 57 shade tolerant species; as well as, for new comer species that consist of 38 species and 39 species of each light response criterion. However, in term of number of individual tree is significantly different among the criterion (Table 1). Light demanding species occupy 76% of total individual tree that consist of 55% pre-fire species and 45% new comer species, and other 24% of total individual tree is shade tolerant species with 65% pre-fire species and 35% new comer species.

Table 1: Number of individual tree and species based on light response and species existence of 2011 survey

Existence of species	Light demanding species		Shade tolerant species		Total	
	No. of individual	No. of species	No. of individual	No. of species	No. of individual	No. of species
Pre-fire species	453	58	165	57	618	115
New comer species	368	38	89	39	457	77
Total	821	96	245	96	1075	192



Number of individual smaller tree 10 – 20 cm DBH were dominated by light demanding species, consist of 31% pre-fire species and 26% new comer species; hence, only 13% of individual trees come from shade tolerant species. All of smaller trees 10 – 20 cm DBH assumed that recruited during the last decade after second fire. Individual trees 20 – 30 cm DBH may be recruited as soon as after second fire that 50% of them come from *M. gigantea*, *V. arborea* and *P. majadun*; and the other 50% come from 36 species.

Individual tree of pre-fire species 30 – 40 cm DBH may be recruited after first fire and survived from second fire that consist of 48 individual trees of 34 species; in average 1 – 2 individual tree for each species, except *P. majadun*. *P. majadun* belong to *Arecaceae* is palm tree with stem size at 30 – 40 cm DBH that some of them survived from fire, both for first and second. New comer species that recruited after first fire and survived from second fire are *V. arborea*, *Cryptocarya nitens*, *Buchanania insignis*, *Dialium patens*, *Croton laevifolius*, *Debasia microsepala*, *Gymnacranthera forbesii* and *Syzygium cf. reaghii*, *S. brachyrachis*, *S. clavatum* and *S. sandakensis*. The last five species are real new comer species, but the last six species are either new comer or result of improving species identification. In 1981 survey, there were *Debasia*, *Gymnacranthera* and *Syzygium* that identified up to genus level (Kartawinata et al. 2008). As well as occurred for tree above 40 cm DBH of *Baccaurea*, *Eugenia*, *Diopyros*, *Litsea*, *Knema* and *Pternandra*.

Table 2: Number of individual tree and species based on light response and species existence of 2011 survey at five diameter classes

Diameter classes	Pre-fire species				New comer species			
	Light demanding		Shade tolerant		Light demanding		Shade tolerant	
	No. of individual	No. of species	No. of individual	No. of species	No. of individual	No. of species	No. of individual	No. of species
10 - 20	336	46	86	44	283	38	52	26
20 - 30	82	17	35	21	78	16	21	15
30 - 40	26	17	22	17	6	5	6	6
40 - 50	5	5	11	9	0	0	6	4
50 - 60	2	2	7	6	0	0	2	2
>60	2	2	4	4	1	1	2	2
Total	453		165		368		89	

Individual trees above 50 cm DBH considered survive from twice fire. They are consist of individual trees from species *Artocarpus champeden* (*Moraceae*), *Eusideroxylon zwageri* (*Lauraceae*), *Anthocephalus chinensis* (*Rubiaceae*), *Durio graveolens* and *Neesia synandra* (*Bombacaceae*), *Diospyros borneensis* (*Ebenaceae*), *Shorea almon*, *Shorea ovalis*, *Vatica umbonata* and *Dipterocarpus cornutus* (*Dipterocarpaceae*) and *Sterculia gilva* (*Sterculiaceae*).

Surprisingly, a light demanding new comer species of *Cratoxylum racemosum* found in above 60 cm DBH during the 2011 survey, as well as shade tolerant species of *Vatica oblongifolia*, *Knema intermedia*, *Antidesma stipulare*, *Gonystylus borneensis*, *Syzygium borneense* and *S. brachyrachis* from 40 to above 60 cm DBH.

### 3.2 Discussion

During three decades with twice fire events, 115 pre-fire species and 77 new comer species regenerated in 1.8 hectare area. Pre-fire species consist of survived individual trees from fire (2.5% of total individual tree belong to 11 species) and new recruitment after first and second

fires that indicate from diameter size of tree at 10 – 20 cm, 20 – 30 cm and 30 – 40 cm. New individual trees can be regenerated from seed bank, rain seed and re-growth of damage tree after first and second fire (van Nieuwstadt and Shield 2005), but it difficult to be differentiated. *M. gigantea* a light demanding pre-fire species and *V. arborea* of light demanding new comer species regenerated after first fire, but the population increase dramatically after second fire and become of dominant species.

The current tree compositions indicate that twice major fire occurred in lowland Dipterocarp forest caused high impact of tree mortality, particularly tree less than 40 cm DBH; and induce some new comer species to recruit. Shade tolerant species tend to resistant to fire than light demanding species that was indicated from the existing number of pre-fire species above 40 cm DBH. In balance species richness between light demanding and shade tolerant species of pre-fire species indicate that in the early succession up to thirteen years after fire, species composition is consist of pioneer species that developing vastly after fire and followed by the climax species of Dipterocarpaceae, Lauraceae, Myristicaceae and Ebenaceae. Survived shade tolerant from fire plays as an important role as source of seed in forest regeneration. In the same time, new comer light demanding species colonize vastly and followed by shade tolerant species belongs to Myristicaceae and Ebenaceae.

*Macaranga gigantea* a light demanding pre-fire species belong to Euphorbiaceae is minor population before fire (9 tree in 10.5 hectares), about 20 trees in 1.65 hectares (Kartawinata et al. 2008; Simbolon 2005), but dramatically increase to 167 trees in 1.8 hectares of 2011 survey. Simbolon (2005), recorded that *M. gigantea* dominated by sapling stage 5 – 10 cm DBH in 2003 survey (five years after second fire), reach about 210 trees in 1.65 hectares. During 2003 – 2011, about 80% of *M. gigantea* survived and develop to pole.

*Vernonia arborea* a light demanding new comer species belong Asteraceae starts to recruit after fire. Five years after second fire about 100 trees 5 – 10 cm DBH and less than 10 trees recruited in 1.65 hectares (Simbolon 2005), and eight years after 90 trees at 10 – 20 cm DBH and 43 trees at 20 – 30 cm DBH. There are 2 trees at 30 – 40 cm DBH found in 2011 survey is assumed survived from second fire that become of seed sources. As reported by Slik et al. (2008), *V. arborea* is included in top ten dominant species in twice burned forest of Samboja 2, 3 and 7 years after fire. As well as, included in top five dominant species in once burned forest of Sungai Wein where located in 15 km distance from Samboja at 2, 3 and 7 years after fire (Slik et al. 2008). In permanent plot of Samboja, population of *V. arborea* shifted to the most second dominant species during 2003 - 2011.

*M. glabra* is shade tolerant new comer species belong to Rutaceae, hadn't been mentioned in 2003 survey (Simbolon 2005), but the population increase dramatically to 49 trees in 1.8 hectares that consist of 80% at 10 – 20 cm DBH and the other 20% at 20 – 30 cm DBH.

*E. zwoageri* (Lauraceae), *D. cornutus* (Dipterocarpaceae) and *P. majadun* (Areaceae) are pre-fire shade tolerant species that included in top 10 of dominant species during three decades after initial forest fire. Some individual trees of the first two species survived from fire due to the size of the stem, above 40 cm diameter and included in the species resistant to fire (Simbolon 2005; van Nieuwstadt and Shield 2005). *P. majadun* that mostly survived were grows in the flat area that haven't been impacted by fire (Simbolon 2005). High mortality of trees 10 – 40 cm DBH happened up to 21 months after fire event and reach about 74%. Several species of Dipterocarpaceae survived from fire due to bark thickness; vascular structure of palm as



benefit for tree to survive from fire and impacted to low mortality less than 10% (van Nieuwstadt & Sheil 2005)

Forty one (41) of 115 pre-fire species regenerated in the twice burned forest of Samboja contain single individual tree and most of them are smaller tree 10 – 20 cm DBH. Those species are highly potential to extinct locally if there is no conservation effort. They are *Archidendron microcarpum*, *Beilschmiedia maingayi*, *Blumeodendron tokbrai*, *Crudia reticulata*, *Dacryodes rostrata*, *Dacryodes rugosa*, *Debaasia caesia*, *Didymocarpus longan*, *Diospyros maingayi*, *Durio graveolens*, *Endospermum diadenum*, *Gardenia forstenii*, *Gardenia tubifera*, *Horsfieldia bracteosa*, *Horsfieldia glabra*, *Hydnocarpus polypetal*, *Kibara coriacea*, *Knema conferta*, *Knema laurina*, *Knema lundensis*, *Koompassia excelsa*, *Koompassia malaccensis*, *Litsea firma*, *Litsea grandis*, *Madhuca magnifolia*, *Monocarpia marginalis*, *Nephelium cuspidatum*, *Parinari oblongifolia*, *Pellacalyx axillaris*, *Poponia hirta*, *Pternandra caerulea*, *Rhodamnia cinerea*, *Santiria megaphylla*, *Shorea acuminatissima*, *Shorea laevis*, *Shorea leprosula*, *Shorea parvifolia*, *Sterculia gilva*, *Eugenia bruneoramea*, *Eugenia opaca* and *Terminalia foetidissima*. Low population of those species also occurred in the permanent plot before fire, less than 5 individual trees in 10.5 hectares (Kartawinata et al. 2008). Number of individual tree before fire is affected to existence species after twice fire. Existed pre-fire species in burned area come from species that contain large individual number at least 10 trees in 10.5 hectares (Kartawinata et al. 2008). Martinez-Garza & Howe (2003) suggested that 1 – 5 individual in a forest fragment less than 10 hectares area still far from minimum viable population value. *C. racemosum* is only the new comer species that was found in above 60 cm DBH in 2011 survey. Possibly, the tree recruited after first fire and survived from second fire, as well as included in fast growing tree. Study in Malaysia found that diameter increment of *C. arborens* seedling which is the same genus to *C. racemosum* is 0.276 mm per week or about 1.5 cm per year; higher than *Alstonia spathulata* and *Stemonurus scorpioides* (Mojjol et al. 2014).

#### 4. CONCLUSION

Three decades period with twice major fire event in 15 years interval, 192 species recorded in the burned forest that consist of 115 pre-fire species and 77 new comer species. Smaller trees 10 – 20 cm DBH is the highest number of trees (70%), 20 – 30 cm DBH (20%), 30 – 50 cm DBH (7.5%) and above 50 cm DBH (2.5%) that considered as survived species to fire and consist of 11 species. Survived species and patch of forest surrounding burned forest play important role as source of seed. Light demanding of pre-fire and new comer species is dominant in twice burned forest up to 90% of tree population with only 10% of shade tolerant population, but in balance composition of species richness. *M. gigantea* is minor light demanding pre-fire species shifted to dominant species and *V. arborea* a light demanding new comer species colonize burned forest vastly. The evidence indicates that the succession process is in early stage, which pioneer species as dominant population. High number of new comer species indicates that twice fire caused big impact to the forest and create large gap in the forest. *P. majadun*, *E. zygageri*, *D. cornutus* and *D. borneensis* considered as survived from twice fire.

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