

The potential risk of tree regeneration failure in species-rich Taba Penanjung lowland rainforest, Bengkulu, Indonesia

AGUS SUSATYA

Department of Forestry, Faculty of Agriculture, Universitas Bengkulu. Jl. WR Supratman, Kota Bengkulu 38371A, Bengkulu, Indonesia. Tel./fax. +62-736-21170, email: agussusatya@unib.ac.id

Manuscript received: 28 May 2018. Revision accepted: 22 September 2018.

Abstract. Susatya A. 2018. *The potential risk of tree regeneration failure in species-rich Taba Penanjung lowland rainforest, Bengkulu, Indonesia. Biodiversitas 19: 1891-1901.* Tropical lowland rain forest is recognized by its high species richness with very few trees per species. It is also known for having tendency to outcrossing of its species with different floral sexualities, which requires the synchronization between flowering of its trees and the presence of pollinators. Such ecological attributes raise possible constraints for the forest trees to regenerate. The objective of the study was to assess the potential risk of failed regeneration for each tree species of the forest. Each of species with dbh of more than 5 cm in a one-ha plot was collected, identified, and its ecological criteria, including rarity, floral sexuality, seed size, and flowering phenology were determined. The potential risk of the failure of regeneration was calculated by summing all scores from Analytical Hierarchical Process of the criteria. The results indicated that the forest consisted of 118 species belonging to 69 genera and 37 families. Rare species accounted to 52.10% of the total species. Of the 118 species, the potential medium risk category contributed to 38.14%, and more than 33% were grouped into very high and high risk or were more prone to failed regeneration in the future. All rare dioecious species were categorized into very high and high risks. Only 21 species (17.79%) are listed in 2017's IUCN red list. Among unevaluated species, 22 and 13 species were respectively included in very high and high potential risk categories. The results revealed more detailed potential risk of failed regeneration of tree species, and can serve as basic information to develop proper conservation management.

Keywords: Bengkulu, dioecy, hermaphrodite, phenology, rarity, rainforest, risk regeneration

INTRODUCTION

Tropical rainforests and their intangible functions are getting more important in recent years due to their vital roles in providing life-support and ecological services such as carbon sequestration, water provision, and prevention of global warming and its negative effects. However, their existences are constantly being threatened by economic as well as human population pressures. Indonesian lowland rain forests especially in Sumatra and Kalimantan Islands, have been undergoing rapid deforestation and degradation as the results of conversions into mainly oil palm plantations as well as into industrial plantation forests which have simpler stand structure. In addition to those external factors, the forests inherently have their own ecological attributes that potentially constrain their abilities to regenerate. In species-rich tropical rain forests, each of their tree species generally consists of very few individual trees (Whitmore 1983; Sakai et al. 1999; Sakai 2001).

Susatya (2007, 2010) studying three different tropical rainforests discovered the similarity of their structural patterns, namely, they were composed of many species, but with very few individual trees. The very low density of tree species appears to be more prevalent to the climax tree species than the pioneer ones (Susatya 2010). Furthermore, unlike pioneer species that have good capabilities to explore wide ecological ranges, the climax tree species have been known to adapt to more limited ecological

ranges as well as more stable environments, and have difficulty to grow under warmer and drier environments (Whitmore 1983). Therefore, rapid environmental changes induced by both climate change and forest degradation will pose constraints for climax tree species to regenerate. Moreover, according to floral sexuality, Bawa et al. (1985) shows that dioecy is common among tropical tree species, which requires at least two different individual trees to perform sexual regeneration.

In the tropical forest, even hermaphrodite species tend to be not self-compatible, and consequently have to do outcrossing (Bawa et al. 1985). Both phenomena require flower synchronization among trees of the same species in order that pollination process can occur. Even if this takes place, then pollination process is still difficult, because different flowering trees can be distant from each other (Whitmore 1983). In the tropical rainforest of Malaysia Peninsular, for example, it requires 32 ha to find two trees of the same species (Poore 1968). Therefore tropical trees must adapt to the rapid environmental alterations; otherwise, they may be threatened by those changes and may face difficulties in regeneration because of their own reproductive biology. The focus of the study was to determine the potential risk of failed regeneration of tree species based on their floral sexualities, tree density, flowering patterns, and seed sizes.

MATERIALS AND METHODS

The research site was located at Taba Penanjung Area within Bukit Daun Protection Forest (*Hutan Lindung Bukit Daun*), Bengkulu Province, Indonesia (Figure 1). This lowland rainforest was well protected and minor illegal logging in the form of cutting small pole (< 10 cm dbh) for social purposes infrequently occurred. Records at Talang Pauh climate station showed that in the last decade, Taba Penanjung area received the annual rainfall around 2848 mm, with no monthly rainfall less than 100 mm. November, December, and January respectively received, 533, 420, 304 mm rainfall, higher than that of the other months. August was known to receive the lowest monthly rainfall (BPS Kab. Bengkulu Tengah 2012). Unusual low monthly rainfall occurred in 1991 and 1994, when September and October got only 3 mm. The monthly relative humidity was 83%, and reached as high as 87.7%, but dropped as low as 75.96%. The average monthly temperature was 26.2 °C, and reached its respective maximum and minimum at 29 °C in August, and 23 °C in October (Susatya 2007). Basic floristic data were collected from a one-hectare plot in 2015. All trees with dbh of > 5 cm were tagged, their diameters measured, and their

herbarium specimens collected. Species identification was carried out in the Herbarium of Universitas Bengkulu (HUB). Species nomenclature followed by Turner (1995). In the case of the absence of tree’s reproductive aspects such as floral sexuality, flowering phenology, and seed size for each species, I relied on the available secondary information including Soerianegara and Lemmens (1994), Lemmens et al. (1995), Sosef et al. (1998), and Plants of Southeast Asia (www.asianplant.net) to collect those data.

To determine the potential risk of failed regeneration (PRR), I applied Analytic Hierarchy Process (AHP) developed by Saaty (1980), and adopted a similar approach from Oktariadi (2009), who used AHP to develop the risk ranking of tsunami in Southern Java. The method of AHP was selected because PRR was calculated by summing the score of different criteria or biological aspects such as density, floral sexuality, flowering phenology, and seed size. AHP is widely used for selecting alternatives from different criteria in different hierarchies. AHP transforms qualitative data into the quantitative ones through pairwise comparisons by experts (Saaty, 1980). Each comparison was conducted to assign a value between two criteria according to their relative importance (Table 1).

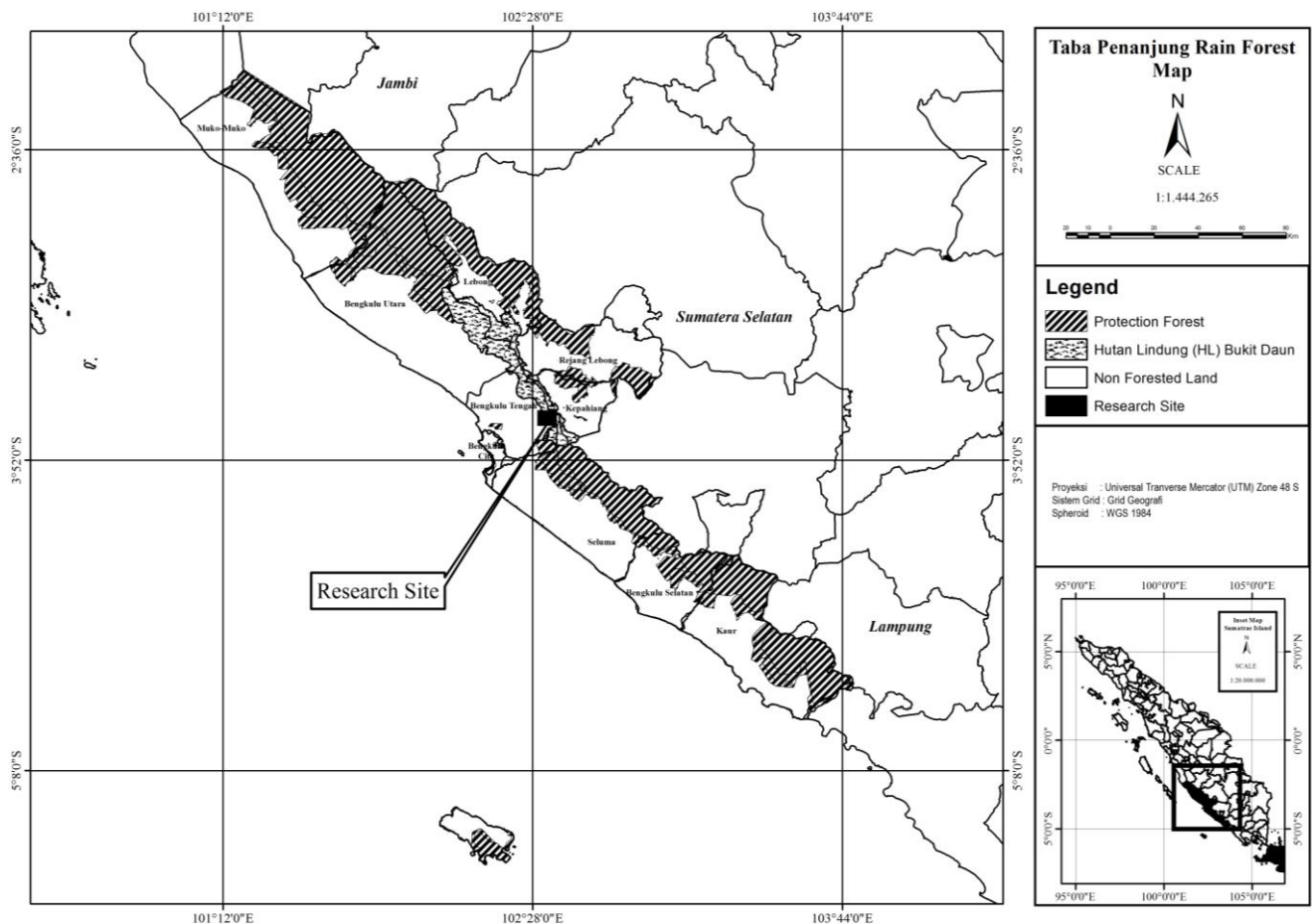


Figure 1. Study site in Taba Penanjung Area within Bukit Daun Protection Forest, Bengkulu Province, Indonesia

Table 1. Assigned values of pair-wise comparisons

Assigned value	Definition	Explanation judgment
1	Equally important	Two criteria or subcriteria are equally important to influence the potential risk of regeneration failure.
3	Moderately more important	One criterion or subcriterion is moderately more important to influence the potential risk of regeneration failure.
5	Much more important	One criterion or subcriterion is much more important to influence the potential risk of regeneration failure.
7	Very much more important	One criterion or subcriterion is very more important to influence the potential risk of regeneration failure.
9	Extremely more important	One criterion or subcriterion is extremely more important to influence the potential risk of regeneration failure.
2, 4, 6, 8	Intermediate judgment value	Values between two consecutive judgments

For the purpose of the study, two hierarchies were established. The first hierarchy consisted of main criteria such as species sexuality (S_i), flowering phenology (P_i), seed size (Z_i), and rarity (R_i) or the number of individual trees per species per ha. Meanwhile, the second hierarchy was subcriteria within sexuality, phenology, seed size, and rarity. Subcriteria of floral sexuality (S_j) included hermaphrodite (S_1), monoecious (S_2), dioecious (S_3), while subcriteria of the flowering phenology (P_j) consisted of once (P_1), twice (P_2), throughout year (P_3), and supra annual (P_4). We defined supra annual category as tree species that performs flowering every more than 1 year, while throughout year was tree species that flowers more or less continuously within a year. The subcriteria of seed size (Z_j) was categorized and developed following Chacon et al. (1998). It consisted of very small (0-4 mm), small (4-8 mm), medium (8-12 mm), large (12-16 mm), and very large (> 16 mm), and was respectively coded as Z_1 , Z_2 , Z_3 , Z_4 , and Z_5 . Subcriteria of the rarity (R_j) consisted of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , and R_7 , which was defined by species with 1, 2, 3, 4, 5-6, > 7 trees per ha, respectively. Three senior ecologists within the Department of Forestry, University of Bengkulu were selected as experts to carry out pairwise comparisons between two criteria or subcriteria. The results of pairwise comparisons were used to construct the matrix of the value judgments, which was further analyzed to find the matrix of the priority rank (eigenvalue). Each eigenvalue of criteria or subcriteria reflected the score of their relative importance in determining the potential risk of failed regeneration.

At each hierarchy level, the consistencies of all scores were checked by comparing their calculated consistency ratios with Saaty's consistency ratio table. If there were inconsistencies in their judgments, all processes of pairwise comparison and analysis were repeated (Saaty 1980, Saaty 2008). Potential risk of failed regeneration, then, was calculated by summing the score of criteria and subcriteria of each species i ($S_i S_j + P_i P_j + Z_i Z_j + R_i R_j$) x 100. Five categories of the potential risks consisting of very high, high, medium, low, and very low were developed. A species was included in either very high, high, medium,

low or very low risks, if it had respectively a total score of PRR between 30.93-36.44, 25.42-30.93, 19.91-25.42, 14.41-19.92, and 8.89-14.40. Potential risk was developed to indicate the relative sensitivity of a species to regeneration failure. It was aimed to extend the interpretation of species threats and the modifications of the systems in determining extinction risk in IUCN at local level. A species with very high-risk category implies that over the time, this species is expected to be more sensitive to the regeneration failure than those in lower risk categories. Any species with very high and high risks will have respectively very high and high probability of regeneration failure in the near future.

RESULTS AND DISCUSSION

Taba Penanjung lowland rainforest consisted of 118 species belonging to 69 genera and 37 families (Supplement). The forest structure was composed mostly of species with a single tree per ha that contributed to 60 species or 50.85% of the total species (Figure 2.A). Only four species, namely *Microcos laurifolia*, *Croton argyratus*, *Elateriospermum tapos*, and *Endospermum diadenum*, had more than 10 trees/ha. *Elateriospermum tapos* (Euphorbiaceae) had the highest density per ha with 31 trees. Following to Ng's category (1978) on species rarity, who defined that any species with a single tree is categorized as rare species, then the forest structure is unproportionally composed of rare species. This rarity was also shown at both genus and family levels in that 8 families or 21.62% of the total families and 20 genera or 28.98% of the total were respectively represented by a single tree. Therefore, any loss of an individual tree of the rare species can result in the loss of species, genus, and family. The unproportional number of rare species composing forest structure appears to be common in Bengkulu such as in Tambang Sawah lower montane forest of Kerinci-Seblat National Park (Susatya 2010), and Talang Tais secondary lowland rainforest (Susatya 2007). Euphorbiaceae was the most diverse family with 11 genera

and 23 species, followed subsequently by Moraceae with 3 genera and 13 species, and Meliaceae with 3 genera and 10 species. It seems that the abundant species of Euphorbiaceae is one of the characters of the floristic composition of Sumatra lowland forest. This is also observed elsewhere in West Sumatra (Hadi et al. 2009, Kohyama et al. 1989). Interestingly, the rare species was also common among the most diverse families. Among 23 species of Euphorbiaceae, 11 species (47.82%) were rare species. Meanwhile, the families of Moraceae and Meliaceae respectively had 33.33% and 40% of their species categorized as rare. Species characterized by very few individual trees per ha potentially faces more difficult to maintain its population.

According to floral sexuality, hermaphrodite species were the most prevalent, contributing to 41.53% of the total species (49 species). Meanwhile, monoecious and dioecious species respectively consisted of 33.05% (39 species), and 25.42% (30 species) (Figure 2.B). Monoecious and dioecious species generally account to 4% and 6% respectively, but the later appears to be more prevalent in the tropics than in temperate regions (Renner 2014). The number of monoecious and dioecious species of Taba Penanjung lowland rain forest was higher than that of Costa Rica wet premontane forest (Breanne 2017) as well as of Central Kalimantan, Indonesia (Brearley et al. 2007). Monoecious and dioecious species of Costa Rica premontane respectively account to 13.10% and 13.70% (Breanne 2017), while the similar categories of Central Kalimantan respectively contribute to 14.70% and 23.49% of the total species (Brearley et al. 2007). Special to dioecious species, its number appears to be more similar than those found at both Sarawak (Ashton 1969) and Pasoh forests (Kochummen et al. 1991).

Dioecious species at both sites respectively account to 26% and 28%. The number of monoecious and dioecious species of the site altogether accounted up to 58,47% of the total species (69 species). This shows that more than half of the total species have to perform outcrossing in order that pollination can occur. Such a process requires both the synchronization of flowering phenology and the presence of pollinators, which could lead to uncertainty on seed production and tree regeneration. The uncertainty is even greater because the sex ratio of dioecious species is male-favored (Queenborough et al. 2009; Gao et al. 2012), and male flowers bloom earlier than their female opposites at certain species (Queenborough et al. 2013).

With regard to tree regeneration, dioecious species have advantages because they tend to yield large seeds, containing more energy (Varmosi et al. 2008), which increase the probability of seedling survivorship. However, dioecious species also face the difficult regeneration, because they have only half of their adult trees to produce seeds (Renner 2014). Dioecious tree species also tend to generate high seed density around their female parent trees, which further lead to high seed predation. It is speculated that the more distant the individual dioecious trees grow from their female parent trees, the higher probability of their seed survivorships and the better seedling recruitment they have due to predation avoidance (Abebbe 2008).

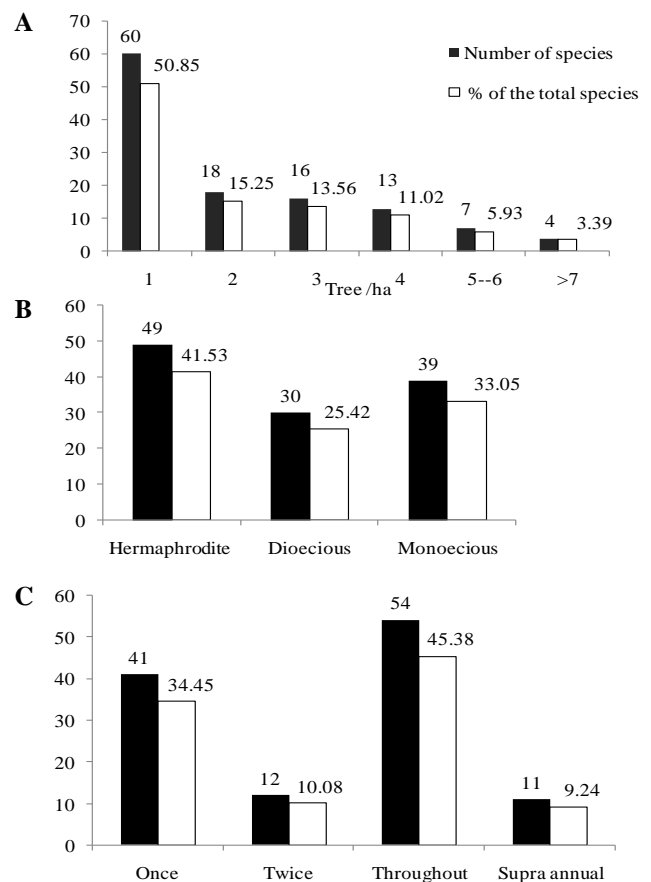


Figure 2. The structure of Taba Penanjung (Bengkulu, Indonesia) lowland rainforest according to: A. Tree density, B. Floral sexuality, C. Flower phenology of its species

Taba Penanjung lowland rainforest has diverse tree species based on flowering phenology. According to flowering phenology, the majority of species of Taba Penanjung rain forest perform either throughout or once flowering phenology (Figure 2.C). Flowering phenology shows the incidence of reproductive efforts of the species, which reflects and will determine the probability of the reproductive success. The throughout flowering species has relatively higher probability to ensure seed production and tree regeneration in the future than the supra annual category, simply because the former produces more frequent flowers and fruit than the later, which only produces flower and fruit once for every two to five years. Flowering phenology is an important factor in tree regeneration, because the length, timing of flowering and fruiting coupled with seasons will determine seed production, seedling mortality, establishment, and growth (Augsburger 1981). Furthermore, the role of environments becomes a pivot point in tree regeneration because the flowering phenology shows a strong correlation with climate, rainfall, and humidity, drought and temperature (Kushwaha et al. 2011; Sulistyawati et al. 2012). Species with throughout flowering contributed to 45.38% of the total species (54 species), while those with once flowering a year accounted to 34.45% (41 species). The number of

species with twice a year and supra annual flowering patterns was not as many as both throughout and once flowering phenologies. Both patterns respectively accounted to 10.08% (13 species) and 9.14% (11 species). The number of species with supra annual flowering in the site was much lower than that of Central Kalimantan (Brearley et al. 2007), and of Lambir hill of Sarawak (Sakai et al. 1999). The supra annual flowering species at those two last sites respectively account to 75%, and 54%. Both forests are dominated by species of Dipterocarpaceae (Brearley et al. 2007; Sakai et al. 1999), which are well known to perform mass flowering or supra annual flowering. Meanwhile, Taba Penanjung rainforest is dominated by species of Euphorbiaceae and Moraceae, which are recorded to have throughout flowering patterns (Whitmore 1983).

Most of species fallen into medium risk category, contributing to 38.14% of the total species. Species with this medium risk indicate that they do not face an immediate risk which may further threaten their regeneration. Other categories namely very high, low, and high risks had almost similar values, ranging from 19.49%, 18.64%, to 17.80% (Figure 3). Both very high and high-risk categories altogether accounted to 37.29%, indicating that more than one-third of the species will face more serious threat to their tree regenerations in the near future.

Twenty three species (Figure 3) from five families were included in very high-risk category, consisting of species from Euphorbiaceae, Myristicaceae, Lauraceae, Flacourtiaceae, Moraceae, and Rubiaceae. Each of these families respectively contributed to 52.17% (12 species), 21.74% (5 species), 13.04% (3 species), and 4.3% (1 species). Of these families, all species of Myristicaceae, namely *Knema globularia*, *Knema glauca*, *Horsfieldia polyspherula*, *Horsfieldia costulata*, and *Gymnacranthera forbesii*, were included in this category. The very high risk category was dominated by dioecious species (22 of 23 species). The only monoecious included in this category was *Artocarpus kemando* (Moraceae). *Artocarpus kemando* was characterized by a single tree per species per ha, large seed category, and supra annual flowering. The combination of these biological characters makes this species have very high risk. A note of this species is that the incident of supra annual flowering is relatively longer than that of the other supra annual flowering species. It has been recorded to not produce flowers within 7 years (Sosef et al. 1998). The very high risk category consisted not only of species with a single tree; in fact, 7 of them had more than one tree per ha, namely *Aporosa acuminate* (2), *Actinodaphne peduncularis* (2 trees), *Drypetes longifolia* (2 trees), *Hydnocarpus curtisi* (3 trees), *Horsfieldia costulata* (2 trees), and *Knema globularia* (3 trees).

All of these species have similar characters such as dioecious and extra large seeds, with various flowering phenology. Among these species, *Aporosa acuminate* and *Actinodaphne peduncularis* are recorded to have ecological disadvantages, where the former has been reported for its low regeneration, and the later has been known for its restricted distribution (Sosef et al. 1998). It

appears that the extra large seed category, and the species density of more than one tree per ha will put the dioecious species into very high risk regardless of their flowering phenologies. The extra large-size seed is generally recalcitrant, which has very fast germination, low capability of dormancy, and high sensitivity to drought (Marcos-Filho 2005). Water content within seeds of this type determines germination success, and varies according to species and habitat quality. For example, the seed of *Shorea roxburghii*, which has habitat with low rainfall, is tolerant to low water content and still be able to germinate when the water content reaches as low as 35%. Meanwhile, the seeds of other species such as *S. almon*, and *S. robusta* can not germinate when the water content is less than 40%. Recalcitrant seeds generally are not able to germinate if the water content reaches as low as 20%-30% (Davies and Ashton 1999). This is the reason why the species with large seeds prefer to grow and become common in the moist condition under canopy trees, but hardly survive in open canopy, or a dry, warm, and disturbed habitat.

Davies and Ashton (1999) raise the issues on the disadvantages for large-seed species. A large seed tends to have lower fecundity and can hardly thrive at a forest gap habitat. On the other hand, a large seed has the advantages of having more energy reserved in its cotyledon. In a good-quality environment, the large seed germinates and grows rapidly, and has high seedling survivorship due to the large energy stored in cotyledon (Arunachalam et al. 2003). On the contrary, the small-size seed size is generally more tolerant to decreasing water contents (Chin et al. 1989). Small-size seeds are categorized as orthodox which generally tolerate drought, and are well known to have long dormancy. Therefore, species with small seeds are able to wait until suitable environments become available for their germination. The presence of gap generating more light intensity, drier and less moist conditions triggers small seeds to germinate and dominate the open habitat (Marcos-Filho 2005). Furthermore, a small seed has many ecological advantages of having wider dispersal, being able to select suitable microclimates, and having high fecundity (Davies and Ashton 1999).

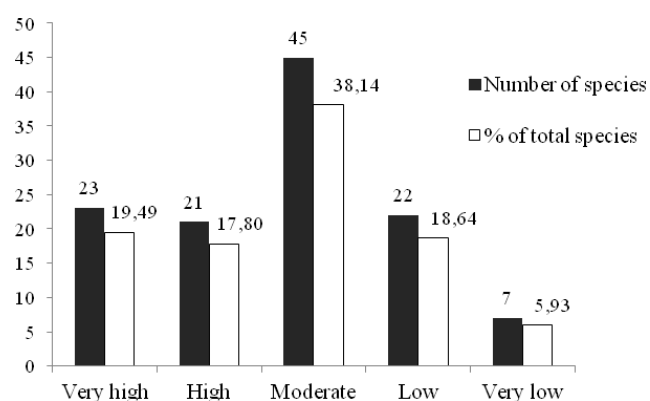


Figure 3. The potential risk of regeneration failure of trees of Taba Penanjung (Bengkulu, Indonesia) lowland rainforest

The majority of the very high-risk category had throughout flowering (12 species), followed by once flowering phenology type (6), while supra annual flowering only consisted of 3 species. This flowering phenology variation shows that the phenology does not determine the very high-risk category. Furthermore, the very high risk comprised 8 and 7 species respectively characterized by extra large and small seed categories. Similar to the phenology, seed size does not determine the very high-risk category either. Therefore, in general, if a species is dioecious and rare, then the species is likely to belong to very high category regardless of seed size and flowering phenology. Dioecious species generally fall into very high-risk category, because of the complexity of reproduction biology. To carry out reproduction efforts, they require flowering synchronization and the presence of pollinators. Dioecious species also show more limited reproduction capacity than those having other flower sexuality types, simply because they have only half of their mature trees contributing to seed production. Their flowering and fruiting successes are also influenced by both the distance between male and female trees and the pollinator movement from male to female trees (Renner 2014). During pollination process, pollinators travel a certain distance which further adds up to the uncertainty of fruit production. The farther the distance between mature male and female trees, the more uncertain pollination process to occur. It was estimated that the closest distance between the same tree species could reach up to 131 m, and the distance between female and male trees could be even farther (Abebbe, 2008). The difficulty of the regeneration of dioecious species is even greater due to the fact that the microclimates beneath male mature trees play a determining role in regeneration. It has been known that seedling and sapling recruitments tend to be greater under the male trees than the female trees (Arai and Kamitani 2005).

A rare species is expected to face the regeneration problem due to its difficulty to maintain its population density. A rare or single-tree per ha species is more likely to experience failed regeneration simply because it statistically has a lower chance to regenerate than those of more than one tree per ha. Forest structure dominated by species having very few individual trees appears a common ecological attribute of species-rich Southeast Asia rainforest (Susatya 2010) and Nigerian rain forest (Adekunle et al. 2013). From the forest tree regeneration perspective, this attribute has been worsened by the fact that even hermaphrodite species tend to be not self-compatible (Bawa 1979; Bawa et al. 1989). However, in this research, a species with a single tree alone does not necessarily determine whether the species belongs to either very high or high-risk categories. In fact, 55% of the total of rare species are classified into either medium risk (27 species) or low risk (5 species) category. Only rare species with either dioecy or monoecy are most likely to belong to either very high or high-risk category. Rare species with high and very high-risk categories accounted up to 12 species and 16 species, respectively.

Moreover, rare hermaphrodite species will fall into medium risk category regardless of seed size and flowering phenology. However, rare hermaphrodite species with both small seed category and throughout phenology such as *Bhesa paniculata* (Celastraceae), *Astronia macrophylla* (Melastomaceae), *Neolamarckia cadamba* (Rubiaceae), *Micromelum minutum* (Rutaceae), and *Rinorea anguifera* (Violaceae) were included in low-risk category. These combined criteria make these five species have better reproductive success as well as better seedling survivorship than the monoecious and dioecious species. This pattern shows that being dioecious or monoecious is more influential in determining very high and high risks than being rare species. As long as a rare species does not belong to dioecious and monoecious categories, it will not be included in either very high or high-risk category.

The high-risk category was composed of 21 species of 10 families (Figure 3), of which family of Meliaceae contributed most with 7 species, while the other nine families only contributed from one to four species. High-risk category comprised various species with all types of the flower sexuality. Monoecious species contributed most with 13 species (61.90%), followed by dioecious species (6 species). Meanwhile, hermaphrodite species only accounted to 2 species. Interestingly, of the 48 hermaphrodite species generally belonging to either medium or very low risk, two were included in high-risk category, namely *Shorea ovalis* and *Palaquium hexandrum*, both of which are characterized by extra large seed and supra annual flowering phenology. The combination of extra large seed and less frequent incidence of flowering and fruiting makes those two species classified into high-risk category. In addition to these biological aspects, an external factor in the form of timber harvesting becomes an imminent threat to these two species. The population of *Shorea ovalis*, the member of commercial light Red Meranti group, is also dwindling due to logging. Like other species of *Palaquium*, *Palaquium hexandrum* faces a reproductive problem, because its flowers hardly reach maturity due to insect predation. If they pass through fruit development, then their fruit suffer high predation by bats, birds, and squirrels (Soerianegara and Lemmens 1994). Furthermore, a special attention has to be made for a rare species of *Diospyros sumatrana* which has been classified into high-risk category. The species appears to face fruit development problem, because it needs long period of time to reach fruit ripening (Lemmens et al. 1995). Such a long period could result in being more vulnerable to fruit predation, which could further lead to lower its regeneration capability.

Not all of the monoecious species fall into a single category. Most of the monoecious species fallen into medium risk (18 species), subsequently followed by high risk (13 species), low risk (6 species), and very high and very lows risk categories which respectively consisted of only 1 species. Monoecious species with one to two trees per ha, large and extra large seed categories, and once flowering pattern will fall into high-risk category. Meanwhile, similar monoecious species with very small seed and throughout phenology (12 species) will belong to

medium risks category. Interestingly, monoecious species with 3-4 trees but with once and supra annual flower will also belong to medium risk category regardless of seed size. It appears that whether a monoecious species will fall into a certain category is not solely defined by its rareness, but also by the seed size and flowering phenology.

Species belonging to medium risk category should not face immediate threats for their regeneration. However, timber harvesting will potentially jeopardize their future. Among the medium risk category (45 species), 26.27% (12 species) are either included into major or minor commercial timbers (Soerianegara and Lemmens 1994; Lemmens et al. 1995). This indicates that these species are likely to become a target for logging in the near future. In addition to a timber harvesting factor, their ecological attributes could potentially increase the risks of several medium risk species. For example, the tree population of *Alstonia angustiloba* has been locally depleted due to logging (Soerianegara and Lemmens 1994), while *Baccaurea racemosa* has been recorded as uncommon species at the lower strata of the Southeast Asia rain forest (Sosef et al. 1998). Furthermore, *Endospermum diadenum* faces a high predation of its seeds and is known to have low seed viability (Soerianegara and Lemmens 1994). Three species of *Polyalthia*, *P. hookeriana*, *P. michaelii*, and *P. rumphii* are noted to have scattered distribution, and their seedlings are sensitive to drought (Sosef et al. 1998).

The hermaphrodite species were included in various categories from medium to very low risk. Rare hermaphrodite species are likely to fall into medium risk, if they have medium to extra large seeds, regardless of their flowering phenologies. However, rare hermaphrodite species with small to very small seed categories and throughout flowering pattern will fall into low risks. Furthermore, hermaphrodite species with more than one tree are most likely to belong to low and very low-risk categories. Hermaphrodite species with more than 4 trees will come up into two different categories depending on their seed sizes. Those with small and medium sizes will end up to very low-risk category, while those with large and extra large seeds will fall into low category. The former consists of *Shorea platyclados*, *Barringtonia lanceolata*, and *Syzygium rostrata*, while the later are *Geunsia hexandra*, *Dillenia excelsa*, *Strombosia javanica*, *Neonauclea gigantea*, *Microcos laurifolia*, *Euonymus javanicus*, and *Cratoxylum sumatrana*.

Of the 118 tree species, only 21 species (17.79%) are listed in 2017's IUCN red list. The other species are listed as not assessed species, meaning the conservation statuses of these species have not been evaluated according to IUCN's criteria. The tree species listed at IUCN consists of 2, 1, 3, and 15 tree species respectively categorized into endangered (E), Vulnerable (V), near threatened (NT), and least concerned (LC). Furthermore, of the 23 species with very high-risk category, only three tree species, namely *Litsea spathacea*, *Knema glauca*, *K. globularia* have been included into least concerned. Of the 21 species with high-risk category, seven are categorized into four different

IUCN's conservation status. Two species, namely *Aglaia speciosa* and *Sterculia oblongata*, are classified as endangered, while *Sterculia parvifolia* is included as vulnerable. Furthermore, three species of Meliaceae, namely *Aglaia odoratissima*, *A. oligophylla*, and *A. rubiginosa*, are grouped into near threatened. Species of *K. glauca*, *K. globularia*, *Litsea spathacea*, *Aglaia tomentosa*, *Sterculia parviflora*, *Archidendron ellipticum*, *Magnolia sumatrana*, *Microcos laurifolia*, *Alstonia angustiloba*, *Bhesa paniculata*, *Euonymus javanicus*, *Payena maingayi*, *P. lanceolata*, *Polyalthia hookeriana*, and *Prunus arborea*, are categorized as the least concerned species. Comparing the IUCN RedList and the results of the potential risk analysis resulted in interesting outcomes. Among the 15 species listed as least concerned by IUCN, nine are classified into medium to low risk categories, which is almost similar to least concerned category, while the other six species, namely *K. glauca*, *K. globularia*, *Aglaia tomentosa*, *Archidendron ellipticum*, *Litsea spathacea*, and *Sterculia oblongata* are either included in high risk or very high-risk category. The first two were very high-risk species characterized by dioecious species with supra annual flowering phenology, while the rest were high-risk monoecious species with large seed category. *S. oblongata*, vulnerable species by IUCN, was classified into high risk. Both seem to be comparable status, where both indicate that in the near future, the species will face difficulty to maintain its population density in order to avoid local extinction. Interestingly, *Shorea platyclados* that has long been classified as endangered species (Ashton 1998), did fall into low risk. Low-risk category of this species indicates that it relatively does not face immediate threat on its tree regeneration locally, and is considered to be able to ensure its future regeneration. The number of tree per ha (4 trees) became the main reason for the species to be classified as low-risk category. Moreover, among the 97 species whose conservation statuses have not been evaluated by IUCN, 22 and 13 were respectively included in very high and high potential risk categories.

The conservation statuses of most of the very high and high-risk tree species have not been evaluated according to IUCN's criteria. IUCN is aware that there is a need for more detailed evaluation for conservation status at local level because differences between global and local threats are very important for determining the status. It further indicates that a species which has been globally categorized into endangered could be the least concerned category due to steady population at a local level. On the other hand, species with least concern status can turn into endangered category due to its small and locally dwindling population (IUCN 2012). The results of this research make more detailed ecological information concerning the potential risk of the failure of tree regeneration available, which is not always provided by IUCN red list documents. The results are very important to serve as both substitutes and guidance at local level for conservation purposes in the absence of conservation status of IUCN of the tree species.

ACKNOWLEDGEMENTS

The author is indebted to members of “Warisan”, who helped in the field works, and also grateful to Astri W. Utami, Sequoia MS. Rhomadhon, and Magnolia GR. Satriorini, who supported logistics during the field work.

REFERENCES

- Abebe GT. 2008. Ecology of regeneration and phenology of seven indigenous species in a dry tropical afro-montana forest, Southern Ethiopia. [Dissertation]. Addis Abeba University, Ethiopia.
- Adekunle VAJ, Olagoke AO, Akindale SO. 2013. Tree species diversity and structure of a Nigerian strict nature reserve. *Trop Ecol* 54 (3): 275-289.
- Arai N, Kamitani T. 2005. Seedrain and seeding establishment of the dioecious trees *Neolitsea sericea* (Lauraceae). Effect of tree sexes and density on invasion into conifer plantation in central Japan. *Canadian J Bot*: 83 (9) 7144-1150
- Arunachalam A, Khan ML, Singh ND. 2003. Germination, growth and biomass allocation as influenced by seed size in *Mesua ferrea*. *L. Turk J Bot* 27: 345-348.
- Ashton P. 1998. *Shorea platyclados*. The IUCN Red List of Threatened Species 1998: e.T33136A9761412. DOI: 10.2305/IUCN.UK.1998.RLTS.T33136A9761412.en
- Ashton PS. 1969. Speciation among tropical forest trees: some deductions in the light of recent evidence. *Biol J Linn Soc* 1: 155-196
- Augsburger C. 1981. Reproduction synchronization of a tropical shrub: experimental studies on effects of pollinator and seed predation in *Hybanthus prunifolius* (Violaceae). *Ecology* 61: 775-788.
- Bawa KS. 1979. Breeding systems of trees in a tropical wet forest. *N Z J Bot*. 17 (521-524).
- Bawa KS, Ashton PS, Primack RB, Terborgh J, Nor SM, Ng FSP, Hadley M. 1989. Reproductive ecology of tropical forest plants. IUBS Special issue-21. International Union Biological Sciences, Paris, France.
- Bawa KS, Perry DR, Beach JH. 1985. Reproductive biology of tropical lowland rainforest trees I. Sexual systems and incompatibility mechanism. *Amer J Bot* 73: 331-480
- BPS Kab. Bengkulu Tengah. 2012. Kabupaten Bengkulu Tengah Dalam Angka Tahun 2012. BPS Kab. Bengkulu Tengah. [Indonesian]
- Breanne H. 2017. Ecological Correlates with Dioecy in the Flora of a Tropical Premontane Wet Forest in Costa Rica. *Distinction Papers* 53. Otterbein University, Westerville, OH
- Brearley FQ, Proctor J, Suriantata, Nagi, J, Dalrymple G, Voyse, BC. 2007. Reproductive phenology over a 20 year period in a lowland evergreen rainforest old central Borneo. *Ecology* 95: 828-839.
- Chacon P, Bustamante R, Henriquez C. 1998. The effect of seed size on germination and seedling growth of *Cryptocarya alba* in Chile. *Revista Chilena de Historia Natural* 71: 189-197.
- Chin HF, Krishnapillay B, Stanwood PC. 1989. Seed Moisture: Recalcitrant vs. Orthodox Seeds. *SSA Special Publication* no. 14. USDA. Madison, WI, USA.
- Davies SJ, Ashton PS. 1999. Phenology and fecundity in 11 sympatric pioneer species of *Macaranga* (Euphorbiaceae) in Borneo. *Amer J Bot* 86 (12): 1786-1792.
- Gao J, Queenborough SA, Chai JP. 2012. Flowering sex ratios and spatial distribution of dioecious trees in a South-East Asian seasonal tropical forest. *J Trop For Sci* 24 (4): 517-527.
- Hadi S, Ziegler T, Waltert M, Hodges JK. 2009. Tree diversity and forest structure in Northern Siberut. Mentawai Island, Indonesia. *J Trop Ecol* 50 (2): 315-327.
- IUCN. 2012. IUCN red list categories and criteria. Version 3.1. Second Edition. IUCN, Gland.
- Kochummen KM, LaFrankie JV, Manokaran N. 1991. Floristic composition of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. *J Trop For Sci* 3: 1-13.
- Kohyama T, Hotta M, Ogino K, Syahbudin, Mukhtar E. 1989. Structure and dynamics of forest stand in Gunung Gadut, West Sumatra. In: Hotta M (ed.). Diversity and plant-animal interaction in equatorial rainforest: report of 1987-1988 Sumatra Research. Kagoshima University, Kagoshima.
- Kushwaha SP, Tripathi SK, Tripathi BD, Sing KP. 2011. Pattern of tree phenology diversity in dry forest. *Act Ecol Sin* 13: 179-185
- Lemmens RHMJ, Soerianegara I, Wong WC. 1995. Plant resources of South-East Asia No 5 (2). Timber trees: Minor commercial timbers. Prosea Foundation, Bogor, Indonesia.
- Marcos-Filho J. 2005. Fisiologia de sementes de plantas cultivadas (Seed physiology of cultivated plants). FEALQ, Piracicaba.
- Ng FSP. 1978. Tree flora of Malaya: A Manual for Forester. vol 3&4. Longman Malaysia Sdn. Bhd., Kuala Lumpur.
- Oktariadi O. 2009. Penentuan peringkat bahaya Tsunami dengan method analytical hierarchy process. (studi kasus: wilayah Pesisir Kabupaten Sukabumi). *Junal Geologi Indonesia* 4 (2): 103-106. [Indonesian]
- Poore MED. 1968. Studies in Malaysian rain forest I. The forest on the Triassic sediments in Jengka Forest Reserve. *J Ecol* 56: 213-216.
- Queenborough SA, Mazer SJ, Vamosi SM, Garwood NC, Valencia R, and Freckleton RP. 2009. Seed mass, abundance and breeding system among tropical forest species: do dioecious species exhibit compensatory reproduction or abundances?. *J Ecol* 97: 555-566.
- Queenborough SA, Humphreys AM, Valencia R. 2013. Sex-specific flowering patterns and demography of the understorey rainforest tree *Iryanthera hostmannii* (Myristicaceae). *Trop Conserv Sci* 6 (5): 637-652.
- Renner SS. 2014. The relative and absolute frequency of angiosperm sexual systems, Dioecy, monoecy, ynodioecy, and update online database. *Amer J Bot* 101 (10): 1588-1596.
- Saaty T. 1980. The Analytic Hierarchy Process. McGraw Hill, New York.
- Saaty T. 2008. Decision making with the analytic hierarchy process. *Intl J Serv Sci* 1 (1): 83-98.
- Sakai S, Momose K, Yumoto T, Nagamitsu T, Nagamasu H, Hamid AA, Nakashizuka T. 1999. Plant reproductive phenology in a lowland Dipterocarp forest, Sarawak, Malaysia. *Amer J Bot* 86: 1414-1436.
- Sakai S. 2001. Phenological diversity in tropical forest. *Popul Ecol* 43: 77-86.
- Soerianegara I, Lemmens RHM. 1994. Plant resources of South-East Asia No 5 (2). Timber trees: Major commercial timbers. Prosea Foundation, Bogor, Indonesia.
- Sosef MSM, Hong LT, Prawirohatmodjo S. 1998. Plant resources of South-East Asia No 5 (3). Timber trees: Lesser-known timbers. Backhuys, Leiden.
- Sulistiyawati E, Mashita N, Setiawan NN, Choesin DN, Suryana P. 2012. Flowering and fruiting phenology of tree species in Mount Papandayan Nature Reserve, West Java, Indonesia. *Trop Life Sci Res* 23 (2): 81-95.
- Susatya A. 2007. The ecology and taxonomy of *Rafflesias* in Bengkulu. [Dissertation]. Faculty of Science and Technology, National University of Malaysia (UKM), Selangor.
- Susatya A. 2010. The diversity and richness of tree species of Tambang Sawah Forest, Kerinci-Seblat National Park. Sumatra Indonesia. *Berk Penel Hayati* 16: 63-67.
- Turner IM. 1995. A catalogue of the vascular plants of Malaya. *Gard Bull Sing* 47: 1-757.
- Vamosi SM, Mazer SJ, Cornejo F. 2008. Breeding systems and seed size in a neotropical flora. Testing evolutionary hypothesis. *Ecology* 89 (9): 61-72
- Whitmore TC. 1983. An introduction for tropical rainforest in Far East Asia. Clarendon Press, Cambridge.

Table S1. Tree species of Taba Penanjung Lowland Rainforest and their potential risks of the regeneration failure

Species	Family	Rarity		Floral sexuality		Seed size		Flowering phenology		Total score	PRR
		Tree/ha	Score	Type	Score	Type	Score	Type	Score		
<i>Actinodaphne peduncularis</i> L	Lauraceae	2	0.238	Dio	0.581	Exl	0.3260	Onc	0.281	34.1826	VH
<i>Aglaia affinis</i> Merr	Meliaceae	2	0.238	Mon	0.309	Med	0.1770	Onc	0.281	25.6374	H
<i>Aglaia faveolata</i> Pannell	Meliaceae	1	0.286	Mon	0.309	Med	0.1770	Onc	0.281	27.8982	H
<i>Aglaia odoratissima</i> Blume	Meliaceae	1	0.286	Mon	0.309	Lrg	0.2960	Onc	0.281	29.1834	H
<i>Aglaia oligophylla</i> Miq	Meliaceae	3	0.19	Mon	0.309	Exl	0.3260	Onc	0.281	24.9858	M
<i>Aglaia rubiginosa</i> (Hiern.) Pannell1	Meliaceae	1	0.286	Mon	0.309	Lrg	0.2960	Onc	0.281	29.1834	H
<i>Aglaia speciosa</i> Blume	Meliaceae	2	0.238	Mon	0.309	Lrg	0.2960	Onc	0.281	26.9226	H
<i>Aglaia tomentosa</i> Teijm ex Binn	Meliaceae	1	0.286	Mon	0.309	Lrg	0.2960	Onc	0.281	29.1834	H
<i>Alstonia angustiloba</i> Miq.	Apocynaceae	1	0.286	Hmp	0.11	Vsm	0.087	San	0.412	24.0132	M
<i>Antidesma brachybotrys</i> Airy Shaw	Euphorbiaceae	1	0.286	Dio	0.581	Sml	0.114	Thr	0.116	31.4313	VH
<i>Antidesma griffithii</i> Hoof. F	Euphorbiaceae	1	0.286	Dio	0.581	Lrg	0.2960	Thr	0.116	33.3969	VH
<i>Antidesma leucocladon</i> Hook.f	Euphorbiaceae	1	0.286	Dio	0.581	Lrg	0.2960	Thr	0.116	33.3969	VH
<i>Antidesma montanum</i> Blume	Euphorbiaceae	2	0.238	Dio	0.581	Vsm	0.087	Thr	0.116	28.8789	H
<i>Antidesma velutinosum</i> Blume	Euphorbiaceae	3	0.19	Dio	0.581	Sml	0.114	Thr	0.116	26.9097	H
<i>Aporosa acuminatissima</i> Merr	Euphorbiaceae	2	0.238	Dio	0.581	Sml	0.114	Onc	0.281	31.8930	VH
<i>Archidendron ellipticum</i> (Blume) Nielsen	Leguminosae	1	0.286	Mon	0.309	Exl	0.3260	Thr	0.116	26.7849	H
<i>Artocarpus anisophyllus</i> Miq.	Moraceae	4	0.143	Mon	0.309	Lrg	0.2960	San	0.412	24.6096	M
<i>Artocarpus elasticus</i> Reinw. ex Blume	Moraceae	4	0.143	Mon	0.309	Exl	0.3260	Onc	0.281	22.7721	M
<i>Artocarpus kemando</i> Miq	Moraceae	1	0.286	Mon	0.309	Lrg	0.2960	San	0.412	31.3449	VH
<i>Astronia macrophylla</i> Blume	Melastomaceae	1	0.286	Hmp	0.11	Sml	0.114	Thr	0.116	19.4208	L
<i>Baccaurea bracteata</i> Mull. Arg	Euphorbiaceae	1	0.286	Dio	0.581	Med	0.1770	Thr	0.116	32.1117	VH
<i>Baccaurea edulis</i> Merr	Euphorbiaceae	1	0.286	Dio	0.581	Exl	0.3260	Onc	0.281	36.4434	VH
<i>Baccaurea racemosa</i> (Reinw. ex Blume) Mull. Arg.	Euphorbiaceae	6	0.095	Dio	0.581	Lrg	0.2960	Thr	0.116	24.4008	M
<i>Baccaurea sumatrana</i> (Miq.) Mull. Arg.	Euphorbiaceae	3	0.19	Dio	0.581	Med	0.1770	Thr	0.116	27.5901	H
<i>Barringtonia lanceolata</i> (Ridl.) Payen	Lecythidaceae	4	0.143	Hmp	0.11	Exl	0.3260	Thr	0.116	14.9751	L
<i>Bhesa paniculata</i> Arn	Celastraceae	1	0.286	Hmp	0.11	Sml	0.114	Thr	0.116	19.4208	L
<i>Bridelia insulana</i> Hance	Euphorbiaceae	3	0.19	Mon	0.309	Sml	0.114	Thr	0.116	19.9737	M
<i>Campnosperma auriculatum</i> (Blume) Hook.f	Anacardiaceae	1	0.286	Mon	0.309	Med	0.1770	Thr	0.116	25.1757	M
<i>Casearia capitellata</i> Blume	Flacourtiaceae	1	0.286	Hmp	0.11	Exl	0.3260	Thr	0.116	21.7104	M
<i>Casearia clarkei</i> King var. <i>kunstleri</i> (King) Ridl.	Flacourtiaceae	1	0.286	Hmp	0.11	Exl	0.3260	Thr	0.116	21.7104	M
<i>Castanopsis inermis</i> (Lindl.) Benth. ex Hook. F	Fagaceae	4	0.143	Mon	0.309	Lrg	0.2960	Onc	0.281	22.4481	M
<i>Chionanthus pluriflorus</i> (Knob) Kew	Oleaceae	2	0.238	Hmp	0.11	Lrg	0.2960	Thr	0.116	19.1256	L
<i>Chionanthus spicata</i> Blume	Oleaceae	1	0.286	Hmp	0.11	Lrg	0.2960	Thr	0.116	21.3864	M
<i>Commersonia bartramia</i> (L) Merr.	Sterculiaceae	2	0.238	Mon	0.309	Sml	0.114	Thr	0.116	22.2345	M
<i>Cratoxylum sumatrana</i> (Jack.) Blume	Hypericaceae	6	0.095	Hmp.	0.11	Sml	0.114	Onc	0.281	13.1472	VL
<i>Croton argyrateus</i> Blume	Euphorbiaceae	15	0.048	Mon	0.309	Med	0.1770	Thr	0.116	13.9659	VL
<i>Dacryodes rugosa</i> (Blume) H. J. Lam	Burseraceae	3	0.19	Dio	0.581	Exl	0.3260	Thr	0.116	29.1993	H
<i>Dillenia excelsa</i> (Jack.) Gilg	Dilleniaceae	6	0.095	Hmp	0.11	Sml	0.114	Onc	0.281	13.1472	VL

<i>Diospyros sumatrana</i> Miq	Ebenaceae	1	0.286	Mon	0.309	Sml	0.114	Onc	0.281	27.2178	H
<i>Drypetes longifolia</i> (Blume) Pax ex. K. Hoffm	Euphorbiaceae	2	0.238	Dio	0.581	Exl	0.3260	Onc	0.281	34.1826	VH
<i>Durio zibethinus</i> L	Bombacaceae	1	0.286	Hmp	0.11	Exl	0.3260	Twi	0.191	22.9479	M
<i>Dysoxylum arborescens</i> (Blume) Miq	Meliaceae	2	0.238	Mon	0.309	Exl	0.3260	Onc	0.281	27.2466	H
<i>Dysoxylum densiflorum</i> (Blume) Miq.	Meliaceae	4	0.143	Mon	0.309	Sml	0.114	Onc	0.281	20.4825	M
<i>Dysoxylum excelsum</i> Blume	Meliaceae	4	0.143	Mon	0.309	Exl	0.3260	Onc	0.281	22.7721	M
<i>Elaeocarpus nitidus</i> Jack	Elaeocarpaceae	1	0.286	Hmp	0.11	Med	0.1770	Onc	0.281	22.8237	M
<i>Elateriospermum tapos</i> Blume	Euphorbiaceae	31	0.048	Mon	0.309	Exl	0.3260	Thr	0.116	15.5751	L
<i>Endospermum diadenum</i> (Miq.) Airy Shaw	Euphorbiaceae	12	0.048	Dio	0.581	Vsm	0.087	Thr	0.116	19.9299	M
<i>Erismanthus obliquus</i> Wall ex. Mull. Arg.	Euphorbiaceae	1	0.286	Mon	0.309	Sml	0.114	Thr	0.116	24.4953	M
<i>Euonymus javanicus</i> Blume	Celastraceae	3	0.19	Hmp.	0.11	Lrg	0.2960	Onc	0.281	19.5873	L
<i>Ficus benjamina</i> L	Moraceae	1	0.286	Mon	0.309	Vsm	0.087	Thr	0.116	24.2037	M
<i>Ficus depressa</i> Blume	Moraceae	1	0.286	Mon	0.309	Vsm	0.087	Thr	0.116	24.2037	M
<i>Ficus fistulosa</i> Reinw. ex. Blume	Moraceae	2	0.238	Mon	0.309	Vsm	0.087	Thr	0.116	21.9429	M
<i>Ficus fulva</i> Reinw. ex. Blume	Moraceae	2	0.238	Mon	0.309	Vsm	0.087	Thr	0.116	21.9429	M
<i>Ficus heteropleura</i> Blume	Moraceae	3	0.19	Mon	0.309	Vsm	0.087	Thr	0.116	19.6821	L
<i>Ficus lepica</i> Blume	Moraceae	2	0.238	Mon	0.309	Vsm	0.087	Thr	0.116	21.9429	M
<i>Ficus ribes</i> Reinw. ex Blume	Moraceae	3	0.19	Mon	0.309	Vsm	0.087	Thr	0.116	19.6821	L
<i>Ficus sundaica</i> Blume	Moraceae	1	0.286	Mon	0.309	Vsm	0.087	Thr	0.116	24.2037	M
<i>Ficus variegata</i> Blume	Moraceae	4	0.143	Mon	0.309	Vsm	0.087	Thr	0.116	17.4684	L
<i>Flacourtia rukam</i> Zoll. et. Moritzi	Flacourtiaceae	3	0.19	Hmp	0.11	Sml	0.114	Onc	0.281	17.6217	L
<i>Geunsia hexandra</i> (Teijsm. et. Binn) Koord	Verbenaceae	4	0.143	Hmp	0.11	Sml	0.114	Thr	0.116	12.6855	VL
<i>Gironniera subaequalis</i> Planch	Ulmaceae	5	0.095	Mon	0.309	Sml	0.114	Thr	0.116	15.4992	L
<i>Gordonia maingayi</i> Dyer	Theaceae	1	0.286	Hmp	0.11	Exl	0.3260	Twi	0.191	22.9479	M
<i>Gordonia multinervis</i> King	Theaceae	3	0.19	Hmp	0.11	Exl	0.3260	Twi	0.191	18.4263	L
<i>Gymnacranthera forbesii</i> (King) Ward	Myristicaceae	1	0.286	Dio	0.581	Exl	0.3260	Twi	0.191	34.9584	VH
<i>Horsfieldia costulata</i> Warb	Myristicaceae	2	0.238	Dio	0.581	Exl	0.3260	Thr	0.116	31.4601	VH
<i>Horsfieldia polyspherula</i> (Hook. F) J. Sinclair	Myristicaceae	1	0.286	Dio	0.581	Lrg	0.2960	Thr	0.116	33.3969	VH
<i>Hydnocarpus curtisii</i> King	Flacourtiaceae	3	0.19	Dio	0.581	Exl	0.3260	Onc	0.281	31.9218	VH
<i>Knema glauca</i> (Blume) Petermann	Myristicaceae	4	0.143	Dio	0.581	Exl	0.3260	San	0.412	31.8696	VH
<i>Knema globularia</i> (Lam.) Warb.	Myristicaceae	3	0.19	Dio	0.581	Exl	0.3260	San	0.412	34.0833	VH
<i>Lansium domesticum</i> Corra	Sapindaceae	1	0.286	Mon	0.309	Exl	0.3260	Onc	0.281	29.5074	H
<i>Litsea cubeba</i> (Laur.) Pers	Lauraceae	4	0.143	Dio	0.581	Lrg	0.2960	Onc	0.281	29.3841	H
<i>Litsea sessilis</i> Boerl.	Lauraceae	1	0.286	Dio	0.581	Med	0.1770	Onc	0.281	34.8342	VH
<i>Litsea spathacea</i> Gamble	Lauraceae	1	0.286	Dio	0.581	Med	0.1770	Onc	0.281	34.8342	VH
<i>Macaranga hosei</i> King ex Hook	Euphorbiaceae	1	0.286	Dio	0.581	Vsm	0.087	Thr	0.116	31.1397	VH
<i>Macaranga hulletii</i> King ex Hook. F.	Euphorbiaceae	1	0.286	Dio	0.581	Sml	0.114	Thr	0.116	31.4313	VH
<i>Macaranga triloba</i> (Blume) Mull. Arg.	Euphorbiaceae	1	0.286	Dio	0.581	Sml	0.114	Thr	0.116	31.4313	VH
<i>Magnolia uvariifolia</i> Dandy ex Noot 2	Magnoliaceae	1	0.286	Hmp	0.11	Med	0.1770	Onc	0.281	22.8237	M
<i>Mallotus leptophyllus</i> Pax et C.K. Hoffm.	Euphorbiaceae	2	0.238	Hmp	0.11	Vsm	0.087	Onc	0.281	19.5909	M
<i>Mallotus auriculatus</i> Merr	Euphorbiaceae	3	0.19	Dio	0.581	Sml	0.114	Thr	0.116	26.9097	H
<i>Mallotus montanus</i> (Mull. Arg) Airy Shaw	Euphorbiaceae	1	0.286	Dio	0.581	Sml	0.114	Thr	0.116	31.4313	VH
<i>Mallotus peltatus</i> (Geisel.) Mull. Arg.	Euphorbiaceae	1	0.286	Dio	0.581	Sml	0.114	Thr	0.116	31.4313	VH
<i>Microcos laurifolia</i> (Hook et Mast) Burret	Tiliaceae	14	0.048	Hmp	0.11	Med	0.1770	Thr	0.116	8.8914	VL
<i>Micromelum minutum</i> (G. Forst.) Wright and Arn.	Rutaceae	1	0.286	Hmp	0.11	Vsm	0.087	Thr	0.116	19.1292	L

<i>Naphelium lappaceum</i> L	Sapindaceae	1	0.286	Hmp	0.11	Exl	0.3260	Onc	0.281	24.4329	M
<i>Neolamarckia cadamba</i> (Roxb) Basser	Rubiaceae	1	0.286	Hmp	0.11	Vsm	0.087	Thr	0.116	19.1292	L
<i>Neonauclea excelsa</i> Merr	Rubiaceae	1	0.286	Hmp	0.11	Med	0.1770	Thr	0.116	20.1012	M
<i>Neonauclea gigantea</i> Merr	Rubiaceae	6	0.095	Hmp	0.11	Med	0.1770	Thr	0.116	11.1051	VL
<i>Ochanostachys amentacea</i> Mast	Olacaceae	2	0.238	Mon	0.309	Lrg	0.2960	Thr	0.116	24.2001	M
<i>Palaquium hexandrum</i> (Griff.) Baill	Sapotaceae	1	0.286	Hmp	0.11	Exl	0.3260	San.	0.412	26.5944	H
<i>Payena lanceolata</i> Ridl.	Sapotaceae	1	0.286	Hmp	0.11	Lrg	0.2960	Thr	0.116	21.3864	M
<i>Payena maingayi</i> Clarke	Sapotaceae	1	0.286	Hmp	0.11	Lrg	0.2960	Thr	0.116	21.3864	M
<i>Pittosporum ferrugineum</i> W.T. Aiton	Pittosporaceae	3	0.19	Hmp	0.11	Vsm	0.087	Thr	0.116	14.6076	L
<i>Polyalthia hookeriana</i> King	Annonaceae	1	0.286	Hmp	0.11	Lrg	0.2960	Twi	0.191	22.6239	M
<i>Polyalthia michaelii</i> C.T. White	Annonaceae	1	0.286	Hmp	0.11	Med	0.1770	Twi	0.191	21.3387	M
<i>Polyalthia rumphii</i> (Blume) Merr.	Annonaceae	1	0.286	Hmp	0.11	Med	0.1770	Twi	0.191	21.3387	M
<i>Pometia pinnata</i> J.R. Forst et G. Frost	Sapindaceae	1	0.286	Mon	0.309	Exl	0.3260	Onc	0.281	29.5074	H
<i>Prainea limpato</i> (Miq.) Beumee	Moraceae	4	0.143	Mon	0.309	Vsm	0.087	Onc	0.281	20.1909	M
<i>Prunus arborea</i> (Blume) Kalkman	Rosaceae	1	0.286	Hmp	0.11	Sml	0.114	Onc	0.281	22.1433	M
<i>Prunus lamponga</i> (Miq.) Kalkman	Rosaceae	3	0.19	Hmp	0.11	Sml	0.114	Onc	0.281	17.6217	L
<i>Quercus argentata</i> Korth	Fagaceae	7	0.048	Mon	0.309	Exl	0.3260	Onc	0.281	18.2976	L
<i>Rhodamnia cinerea</i> Jack	Myrtaceae	1	0.286	Hmp	0.11	Med	0.1770	Thr	0.116	20.1012	M
<i>Rinorea anguifera</i> (Lour.) Kuntze	Violaceae	1	0.286	Hmp	0.11	Vsm	0.087	Thr	0.116	19.1292	L
<i>Shorea ovalis</i> (Korth.) Blume	Dipterocarpaceae	1	0.286	Hmp	0.11	Exl	0.3260	San	0.412	26.5944	H
<i>Shorea parvifolia</i> Dyer	Dipterocarpaceae	3	0.19	Hmp	0.11	Med	0.1770	San	0.412	20.4636	M
<i>Shorea platyclados</i> Slooten ex. Fox	Dipterocarpaceae	4	0.143	Hmp	0.11	Lrg	0.2960	San	0.412	19.5351	L
<i>Sterculia oblongata</i> R. Br.	Sterculiaceae	1	0.286	Mon	0.309	Sml	0.114	San	0.412	29.3793	H
<i>Sterculia parviflora</i> Roxb. ex. G. Don	Sterculiaceae	1	0.286	Mon	0.309	Lrg	0.2960	Onc	0.281	29.1834	H
<i>Strombosia javanica</i> Blume	Olacaceae	6	0.095	Hmp	0.11	Med	0.1770	Onc	0.281	13.8276	VL
<i>Symplocos crassipes</i> C. B. Clarke	Symplocaceae	2	0.238	Hmp	0.11	Sml	0.114	Twi	0.191	18.3975	L
<i>Syzygium flosculiferum</i> (M. R. Hensd.) Sreek	Myrtaceae	2	0.238	Hmp	0.11	Lrg	0.2960	Twi	0.191	20.3631	M
<i>Syzygium kunstleri</i> (King). Bahadur et R.C. Gour	Myrtaceae	1	0.286	Hmp	0.11	Lrg	0.2960	Twi	0.191	22.6239	M
<i>Syzygium lineatum</i> (DC) Merr. ex L. M. Terry	Myrtaceae	1	0.286	Hmp	0.11	Lrg	0.2960	Onc	0.281	24.1089	M
<i>Syzygium politum</i> (King). I.M. Turner	Myrtaceae	1	0.286	Hmp	0.11	Sml	0.114	Twi	0.191	20.6583	M
<i>Syzygium rostrata</i> Blume	Myrtaceae	4	0.143	Hmp	0.11	Lrg	0.2960	Twi	0.191	15.8886	L
<i>Urophyllum macrophyllum</i> Korth	Rubiaceae	1	0.286	Dio	0.581	Sml	0.114	Thr	0.116	31.4313	VH
<i>Vitex vestita</i> Wall. ex Schauer	Verbenaceae	1	0.286	Hmp	0.11	Sml	0.114	Onc	0.281	22.1433	M
<i>Xylopi caudata</i> Maingay ex. Hook. F. et Thomson	Annonaceae	2	0.238	Hmp	0.11	Lrg	0.2960	Onc	0.281	21.8481	M
<i>Xylopi elliptica</i> Hook.f and Thomson	Annonaceae	1	0.286	Hmp	0.11	Lrg	0.2960	Onc	0.281	24.1089	M

Note: Floral sexuality code; Dioecious (Dio), Monoecious (Mon), Hermaphrodite (Hmp). Seed size code; Extra large (Exl), Large (Lrg), Medium (Med), Small (Sml), Very small (Vsm). Flowering phenology code; Once (Onc), Twice (Twi), Throughout (Thr), Supra annual (San). PRR refers to the potential risk of regeneration failure. PRR code: Very high risk (VH), High risk (H), Medium risk (M), Low risk (L), and Very low (VL).

BIODIVERSITAS

Volume 19, Number 5, September 2018

Pages: 1891-1901

ISSN: 1412-033X

E-ISSN: 2085-4722

DOI: 10.13057/biodiv/d190541