Soil Seed Bank of Two Karst Ecosystems in Bogor, Indonesia: Similarity with the Aboveground Vegetation and Its Restoration Potential

Winda Utami Putri 1*, Ibnul Qayim 1, Abdul Qadir 2

1 Department of Biology, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Bogor, Indonesia
2 Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Bogor, Indonesia

ABSTRACT

Karst ecosystem in Bogor is currently threatened by mining activities. Restoration of the disturbed karst areas is urgently required. Seed banks are considered as an important potential seed sources for restoration. This study was conducted to quantify the composition and species diversity of the aboveground vegetation and the seed bank. The study determined the correspondence between the seed bank with the aboveground vegetation in relation with ecosystem restoration. Twenty 6 m × 6 m vegetation plots were established. A total of sixty soil samples were taken from the study sites. The seed bank was studied using germination experiment. All plant species in the vegetation plots and seedlings growing from all soil samples were identified and the number was counted to determine the composition, index of diversity, and index of similarity. There were 80 species from 41 families found in the seed bank in Mt. Nyungcung, dominated by Clidemia hirta (Melastomataceae), whereas 50 species from 29 families found in Mt. Kapur with Cecropia peltata (Urticaceae) dominated the site. Diversity index of Mt. Nyungcung and Mt. Kapur seed banks were 2.09 ± 0.21 and 1.78 ± 0.47 respectively. The similarity index between seed bank and the aboveground vegetation in the two study sites were 32.86% and 27.66% respectively. Mt. Nyungcung seed bank was more diverse than Mt. Kapur. The similarity between the seed bank with the aboveground vegetation in the two study sites were low. Further assessment is needed to determine the role of the seed bank of Mt. Nyungcung and Mt. Kapur in the restoration of the ecosystems.

Keywords: Diversity, germination, karst, soil seed bank, vegetation

INTRODUCTION

Karst area is natural landscape of sedimentary rock that consists primarily of calcium carbonate. Tectonic movements lifted the karst above sea level after they were formed million years ago by calcium secreted marine organism. The total of karst area in Indonesia is 145,000 km², 15% of which are protected [1]. Karst area possesses high ecological values especially in term of species endemicities. Karst vegetation has important role in securing water supply for the surrounding environment by absorbing and supplying water. The vegetation also supports the existence of other components of the ecosystem such as wild animals.

Soil seed bank (hereafter referred as seed bank) is a reservation of viable and ungerminated seeds either in the above or belowground of a habitat [2]. Ecologically, seed banks acts as seeds reservation that will prevent further extinctions of vulnerable local species [3]. The seed bank has also become an important part in plant regeneration process after disturbance [4].

The karst areas in Indonesia including the study sites are currently threatened by mining activities that has decreased habitat numbers, plant numbers, and species numbers as well as causing the reduction of endemic species. Restoration of the disturbed areas is urgently required for ecosystem recovery. A study on seed bank in karst ecosystem would provide information on specific plant species that can be employed for restoration. The
study was conducted to quantify the composition and species diversity of the standing vegetation and the seed bank. The study determined the correspondence between the seed bank and the aboveground vegetation in relation with ecosystem restoration.

**MATERIALS AND METHODS**

This study was conducted on September 2015 until August 2016. Data were gathered from karst ecosystem in Mount (Mt.) Nyungcung (06°27’15.3” S and 106°38’45.8” E) and Mt. Kapur (06°32’59.8” S and 106°41’16.1” E), both are in Bogor Regency. Both sites were mined from around nineteen eighties. Mining activity in Mt. Nyungcung was ended around 2005 while in Mt. Kapur is still operating.

**Vegetation data and soil sample collection**

Twenty plots were established to collect data on vegetation composition. The size of each plot was 6 m × 6 m, which was determined by preliminary investigation on the species number plotted in a graph from previous study conducted by [5]. All plant species in the plot were identified directly in the field based on their morphological characteristics. Herbarium voucher of unidentified plants was collected for further identification at Kebun Raya Bogor. Vegetation data were used to compare the composition of the vegetation with the composition of the seed bank. A total of sixty soil samples were taken from twenty vegetation plots. The size of each plot was 1 m × 1 m with 5 – 10 cm depth. Vegetation and soil plots was placed using purposive sampling technique. The plots in Mt. Nyungcung were placed at 193 – 218 m above sea level (asl) and in Mt. Kapur at 258 – 310 m asl.

**Germination experiment**

Seed bank testing was conducted using the germination experiment. All soil samples from the same site were composited. The composited soil was placed in 44 cm × 35 cm × 10 cm germination plastic trays which are filled with 5 – 7 cm depth of sterilized sand. Germination experiment started by covering all the germination trays using clear plastic cover for the first two months to maintain the temperature and humidity in favorable condition for the seeds to germinate. The germination trays were then transferred to the glass house after the seeds germinated to allow them to grow into seedlings for identification purposes. Seedling identification were visually done by observing specific morphological characters of a plant.

**Data analysis**

Shannon’s diversity index (H’) [6] was determine using the following formula:

$$H' = - \sum_{i=1}^{n} p_i \ln p_i$$

Note:

- $p_i$: proportion of individuals belonging to the $i^{th}$ species

Margalef species richness index (R) [7] was obtain by formula:

$$R = \frac{S - 1}{\ln(N)}$$

Note:

- $S$: Number of species
- $N$: Total number of individual plant

Shannon’s evenness index (E) [8] was calculated using formula:

$$E = \frac{H'}{\ln(S)}$$

Note:

- $H'$: Shannon’s diversity index
- $S$: Number of species

The similarity of species composition in the seed bank and the aboveground vegetation on each location were analyzed using Sorensen Index of Similarity [9] formula:

$$IS = \frac{2J}{a + b} \times 100\%$$

Note:

- $J$: Number of the same species in a and b
- $a$: Number of Species in a
- $b$: Number of species in b

Independent sample t-test were performed on the diversity, evenness, and species richness index. Data analysis were conducted using *Microsoft Excel* and *SPSS 22* software.

**RESULTS AND DISCUSSION**

**Composition of the aboveground vegetation and its diversity**

The field study found 354 plants belonging to 60 plant species from 40 families in the aboveground vegetation of Mt. Nyungcung. *Coffea liberica* (Rubiaceae) dominated the site followed by *Antidesma montanum* (Phyllanthaceae) (Table 1). The aboveground vegetation in Mt. Nyungcung consisted mostly of plants belonging to Myrtaceae, Pandanaceae, Phyllanthaceae, Rubiaceae and Sapindaceae. Karst ecosystem in Mt. Kapur had
Table 1. List of top ten most abundant plant species composing the aboveground vegetation

| Location | Species                        | Total (ind) |
|----------|--------------------------------|-------------|
| Mt. Nyungcung | Coffea liberica Hiern      | 47          |
|          | Antidesma montanum Blume  | 29          |
|          | Tristaniopsis sp.           | 27          |
|          | Pandanus sp.               | 21          |
|          | Chrysophyllum flexuosum Mart. | 19         |
|          | Selaginella sp.            | 19          |
|          | Guioa diplopetala (Hassk.) Radlk. | 18    |
|          | Microcos hirsuta (Korth.) Burret | 12      |
|          | Dioscorea hispida Dennst. | 9           |
|          | Dracaena elliptica Thunb. & Dalin. | 9        |
| Mt. Kapur | Strophioblachia fimbrialyx Boerl. | 76      |
|          | Stachytarpheta indica (L.) Vahl | 63      |
|          | Arytera litoralis Blume    | 50          |
|          | Mallotus floribundus (Blume) Müll.Arg. | 46    |
|          | Alchornea rugosa (Lour.) Müll.Arg. | 44     |
|          | Clausena excavate Burm.f. | 37          |
|          | Callistria calothyrsus Meisn. | 33       |
|          | Bauhinia championii (Benth.) Benth. | 18     |
|          | Antidesma montanum Blume  | 15          |
|          | Bridelia tomentosa Blume  | 12          |

more plant number but fewer number of plant species compare to that of Mt. Nyungcung. There were 528 plants belonging to 46 species from 23 families, in the site. The most abundant species were Strophioblachia fimbrialyx (Euphorbiaceae) followed by Stachytarpheta indica (Verbenaceae). In Mt. Kapur, the plants mostly belong to Anacardiaceae, Euphorbiaceae, Leguminosae, Rutaceae, Sapindaceae and Verbenaceae. The complete list of the species is given as Appendix 1.

Pioneer species such as Macaranga rhizinoides and Macaranga tanarius both Euphorbiaceae were recorded in the aboveground vegetation of the two sites indicated early successional stage of the karst ecosystem. These species can withstand hostile environment of the karst area including high light intensity, thin solum and drought. The relatively open area of karst and the high light intensity that were varied between $417 \text{–} 484 \times 10^2$ lux in Mt. Nyungcung and $1,816 \text{–} 1,823 \times 10^2$ lux in Mt. Kapur supported the growth of several species such as Cecropia peltata (Urticaceae) and Melastoma malabathricum (Melastomataceae).

The presence of several invasive species such as Coffea liberica (Rubiaceae) and Piper aduncum (Piperaceae) were also recorded in the aboveground vegetation of Mt. Nyungcung and Mt. Kapur. The invasive species may have been colonizing the two study sites after disturbance and considered to negatively impact the natural environment by replacing indigenous species [10]. Their presence at a site may be part of the condition leading to assessment that restoration is needed [11].

Diversity index of Mt. Nyungcung was higher compare to that of Mt. Kapur. The aboveground vegetation of Mt. Nyungcung had $2.65 \pm 0.54$ of diversity index, while Mt. Kapur had $2.51 \pm 0.71$. Higher value of Mt. Nyungcung diversity index showed by higher species number and more even species distribution which was indicated by higher species richness and evenness index. Value of species richness and evenness index in Mt. Nyungcung were $4.56 \pm 1.21$ and $0.95 \pm 0.15$ respectively, while in Mt. Kapur were $2.46 \pm 0.84$ and $1.07 \pm 0.25$. The species richness in the two study sites were significantly different ($t = 4.515, df = 18, P = 0.00$).

Seed bank characteristics: composition and species diversity

Mount Nyungcung seed bank comprised of 2602 seedlings belonging to 80 plant species from 41 families. The most abundant species were Clidemia hirta followed by M. malabathricum both Melastomataceae (Table 2). The largest family composing Mt. Nyungcung seed bank were Melastomataceae, subsequently followed by Rubiaceae, Primulaceae, Poaceae and Solanaceae.

The total number of plant species in the seed bank of Mt. Nyungcung were higher compare to that of Mt. Kapur. In Mt. Kapur seed bank, 1280 seedlings belonging to 50 plant species from 29 families were recorded. C. peltata (Urticaceae) was the most abundant species in Mt. Kapur. Urticaceae was the largest family composing Mt. Kapur seed bank followed by Selaginellaceae, Poaceae, Erythroxylaceae and Verbenaceae. The complete list of the species is given as Appendix 2.

Plants in Mt. Nyungcung seed bank consisted of 24.36% trees, 28.21% shrubs and 24.36% herbs while in Mt. Kapur consisted of 30.61% trees, 24.49% shrubs and 28.57% herbs. Composition of the seed bank of Mt.
Nyungcung and Mt. Kapur were dominated by shrubs and herbs. The tree species in both study sites were relatively low but in Mt. Kapur the numbers were slightly higher. Forests in Karst area have relatively smaller number of tree species compared to forests with thick solum [12]. Field observation showed that the Mt. Kapur solum was a little bit thicker by approximately 5-10 cm than Mt. Nyungcung. Therefore, trees in Mt. Kapur have bigger chances to survive and store their seeds in the soil.

The studied seed bank was dominated by small-seeded species while the standing vegetation was dominated by large-seeded species. Annual species such as *Laportea aequiloba* (Urticaceae), *Solanum americanum* (Solanaceae), and *Momordica charantia* (Cucurbitaceae) were recorded present in the seed bank. Short-lived annual species maintains its existence by relying their regeneration on seeds, therefore accumulates their seeds in the seed bank.

The study also recorded the presence of few long-lived dominant trees species that has seeds accumulation prevention self-mechanism which was largely due to trade-offs between seed size and seed production and between seed size and persistence. Large seeds typically produced in lower numbers than small seeds and generally accumulating in the seed bank more ineffectively [13, 14].

The seed bank had been classified into transient and persistent, depending on the seeds persistence in the soil whether less or more than a year [15]. The length of the germination experiment suggested that the studied seed banks were mostly transient. However, we also confirmed the presence of persistent seed bank. In the studied site where invasion process occurred, the seed bank had become dominated by seeds of weedy species, which typically possess large, persistent seed banks [16]. Pioneer species which were present after disturbance in the two studied sites had also formed the persistent seed bank by producing persistent seeds that remain in the seed bank [17].

Species diversity index of Mt. Nyungcung seed bank were significantly different from those of Mt. Kapur (t = 3.117, df = 57, P = 0.04). Mt. Nyungcung had 2.09 ± 0.21 of diversity index, while Mt. Kapur had 1.78 ± 0.47. Species diversity in Mt. Nyungcung was higher than that of Mt. Kapur. The species diversity of the seed bank has positive correlation with the species diversity of the aboveground vegetation [20]. Value of the species richness index in Mt. Nyungcung and Mt. Kapur were 3.97 ± 0.53 and 2.82 ± 0.64 respectively. Species richness index of Mt. Nyungcung seed bank were significantly different from those of Mt. Kapur (t = 7.490, df = 57, P = 0.00). Evenness index in Mt. Nyungcung and Mt. Kapur were 0.72 ± 0.09 and 0.76 ± 0.19 respectively. Number of plant species in Mt. Nyungcung seed bank was higher and more evenly distributed between the species.

The species diversity of the two seed banks were in the same level with the aboveground vegetation. The species diversity was moderate based on [21] classification but the species composition was different. In the coming pe-

| Location      | Species                             | Total |
|---------------|-------------------------------------|-------|
| Mt. Nyungcung | *Clidemia hirta* (L.) D. Don         | 589   |
|               | *Melastoma malabathricum* L.         | 586   |
|               | *Musaenda acuminata* Blume           | 323   |
|               | *Embelia ribes* Benth.               | 207   |
|               | *Centotheca lappacea* (L.) Desv.     | 115   |
|               | *Centrosema pubescens* Benth.        | 70    |
|               | *Solanum torvum* Sw.                 | 69    |
|               | *Peperomia pellucida* (L.) Kunth     | 66    |
|               | *Melicope lanu-ankenda* (Gaertn.)   | 47    |
|               | *Cecropia peltata* L.                | 44    |
|               | *Cecropia peltata* L.                | 646   |
| Mt. Kapur     | *Selaginella* sp.                    | 110   |
|               | *Erythrospermum cuneatum* (Miq.)     | 76    |
|               | *Stachytarpha indica* (L.) Vahl      | 73    |
|               | *Piper aduncum* L.                   | 69    |
|               | *Centotheca lappacea* (L.) Desv.     | 64    |
|               | *Clidemia hirta* (L.) D. Don         | 40    |
|               | *Xanthosoma* sp.                     | 22    |
|               | *Antidesma montanum* Blume           | 17    |
|               | *Mallotus floribundus* (Blume)       | 14    |

Table 2. List of top ten most abundant plant species composing the seed banks
riod, the seed bank will probably increase the species diversity of the standing vegetation by adding the number of species present in vegetation.

**Similarity between seed bank and the aboveground vegetation**

Result of germination experiment showed that there were 118 and 84 plant species in the seed bank and the aboveground vegetation of Mt. Nyungcung and Mt. Kapur. From that numbers, 49.15% were present in the seed bank but absent in the aboveground vegetation, 31.36% occurring the aboveground vegetation but absent from the seed bank of Mt. Nyungcung. In Mt. Kapur 45.24% of the species were present in the seed bank but absent in the aboveground vegetation, 39.29% present in the aboveground vegetation but absent from the seed bank. These findings were in agreement with few other studies on seed bank which showed that there were plant species recorded in the seed bank but were not part of the current standing vegetation [22,23].

The similarity index between the seed bank and the aboveground vegetation of Mt. Nyungcung was 32.86% while in Mt. Kapur was 27.66%. The species similarity was low, as found in most studies comparing the composition of established vegetation and seed bank [24]. The seed banks were poor predictors of the aboveground vegetation of Mt. Nyungcung and Mt. Kapur. Many of the plant species found in the seed bank were absent in the aboveground vegetation. Result of germination experiment was in agreement with [25, 26] finding which showed that there was no strong relationship between species composition of the seed bank with the species composition of its aboveground vegetation.

There were two factors that might explain the low similarity between the seed bank and the aboveground vegetation in the study site. The first factor was the el nino occurrence in Indonesia when the study was conducted (reported by The Indonesian Agency for Meteorology, Climatology, and Geophysics). El nino caused several plant species in the two study sites unable to survive, but may have stored seeds in the seed bank prior to their deaths. Second, the presence of invasive species in the aboveground vegetation may cause another plant species to disappear because of a range of mechanisms associated with an invasion [27], but their seeds might still be present in the seed bank. Thus, several plant species recorded in the seed bank were not present in the aboveground vegetation. The similarity between the seed bank and the aboveground vegetation is low at heavily invaded or long term invaded sites [28] just like Mt. Nyungcung and Mt Kapur.

**Seed bank and ecosystem restoration**

Seed banks play important roles in conservation of plant species. Components of species diversity in the form of seed bank are readily available to support the ecosystem restoration after disturbances. Seed banks of the two studied sites have low similarity with the aboveground vegetation, thereby affecting its ability in supporting the ecosystem restoration.

There are two possibilities that explain the low similarity between seed bank and aboveground vegetation, each has different consequences for the ecosystem restoration (if we exclude the seeds of the invasive species in the seed bank). First, the seed bank stored seeds from trees that were previously occupied the aboveground vegetation but no longer existed. The consequence of this possibility is that even if the similarity was low, the seed bank can still support the ecosystem recovery and allows natural restoration to occur. Second, the seed bank stored seeds that were carried by dispersal agents such as animals and humans from outside the ecosystem. They bring different consequences to that of the first possibility. The seed bank will have limitation in supporting the ecosystem recovery of the area. Therefore, a man managed restoration is needed. Further analysis of the aboveground vegetation composition prior to the mining activity needed to be done to determine the capacity of the current seed bank in supporting the ecosystem recovery.

The presence of invasive species in the studied seed banks may indicate a constraint in ecosystem restoration. Invasion process may change the composition of the native species seed bank, thereby affecting its restoration potential. Information on the origin of the seeds in the seed bank are required to develop an effective restoration strategy. The restoration potential of the seed bank as the total biodiversity reservoir in the site is likely to be restored if the invasive species could be controlled or eliminated.

**CONCLUSION**

Mt. Nyungcung vegetation and seed bank was more diverse than Mt. Kapur. The similarity between the seed bank with the aboveground vegetation in the two sites were low. The seed banks were poor predictors of the aboveground vegetation.

In term of ecosystem recovery, a further analysis of the aboveground vegetation composition prior to the mining activity needed to be done. The information
from the analysis can determine the capacity of the current seed bank in supporting the ecosystem recovery of Mt. Nyungcung and Mt. Kapur.

**ACKNOWLEDGMENT**

This study was funded by the Indonesia Endowment Fund for Education, Ministry of Finance of The Republic of Indonesia. We are thankful for all the supports especially research facilities from Bogor Agricultural University and Kebun Raya Bogor.

**REFERENCES**

1. Clements R, Sudhi NS, Schilthuizen M, Ng PKL (2006) Limestone karst of Southeast Asia: imperiled arks of biodiversity. BioScience 56 (9): 733 – 742. doi: 10.1641/0006-3568(2006)56[733:IKOSAI]2.0.CO;2.

2. Baskin CC, Baskin JM (2001) Seeds: ecology, biogeography, and evolution of dormancy and germination. San Diego, Academic Press.

3. Aparicio A, Guisande R (1997) Replenishment of the endangered *Echinospartum algibicum* (Genisteeae, Fabaceae) from the soil seed bank. Biological Conservation 81 (3): 267 – 273. doi: 10.1016/S0006-3207(96)00154-1.

4. Hyatt LA, Casper BB (2000) Seed bank formation during early secondary succession in a temperate deciduous forest. J Ecol. 88: 516-527. doi: 10.1046/j.1365-2745.2000.00465.x.

5. Satyanti A, Kusuma YWC (2010) Ecological study in two quarried limestone karst hills in Bogor West Java: vegetation structure and floristic composition. Biotropia 17 (2): 115 – 129.

6. Dice LR (1945) Measures of the amount of ecologic association between species. Ecology 26 (3): 297–302. doi: 10.2307/1932409.

7. Clifford HT, Stephenson W (1975) An introduction to numerical classification. London, Academic Express.

8. Ludwig JA, Reynolds JF (1988) Statistical ecology a primer on methods and computing. New York, John Wiley and Sons, Inc.

9. Shannon CE, Weaver, W (1949) The mathematical theory of communication. Urbana, University of Illinois Press.

10. Rogers HM, Hartemink AE (2000) Soil seed bank and growth rates of an invasive species, *Piper aduncum*, in the lowlands of Papua New Guinea. Journal of Tropical Ecology 16 (2): 243 – 251.

11. D’Antonio CD, Meyerson LA (2002) Exotic plant species as problems and solutions in ecological restoration: A synthesis. Restoration Ecology 10 (4): 703 – 713. doi: 10.1046/j.1526-100X.2002.01051.x.

12. Crowther J (1982) Ecological observations in a tropical karst terrain, West Malaysia. 1. Variations in topography, soils and vegetation. Journal of Biogeography 11 (1): 65 – 78. doi: 10.2307/2844731.

13. Fenner M, Thompson K (2005) The ecology of seeds, 2nd ed. Cambridge, Cambridge University Press.

14. Thompson K, Bakker JP, Bekker RM, Hodgson J (1998) Ecological correlates of seed persistence in the soil in the north-west European flora. Journal of Ecology 86 (1): 163 – 169. doi: 10.1046/j.1365-2745.1998.00240.x.

15. Thompson K, Band SR, Hodgson JG (1993) Seed size and shape predict persistence in soil. Functional Ecology 7 (2): 236 – 241. doi: 10.2307/2389893.

16. Gioria M, Osborne BA (2009) Assessing the impact of plant invasions on soil seed bank communities: Use of univariate and multivariate statistical approaches. Journal of Vegetation Science 20 (3): 547 – 556. doi: 10.1111/j.1654-1103.2009.01054.x.

17. Hopfensberger KN (2007) A review of similarity between seed bank and standing vegetation across ecosystems. Oikos 116 (9): 1438 – 1448. doi: 10.1111/j.0030-1299.2007.15818.x.

18. Sheil D, Padmanaba M (2011) Innocent invaders? A preliminary assessment of Cecropia, an American tree, in Java. Plant Ecology and Diversity 4 (2 – 3): 279 – 288. doi: 10.1080/17550874.2011.610371.

19. Gioria M, Osborne BA (2010) Similarities in the impact of three large invasive plant species on soil seed bank communities. Biological Invasions 12 (6): 1671 – 1683. doi: 10.1007/s10530-009-9580-7.

20. Leckie S, Vellend M, Bell G et al. (2000) The seed bank in an old-growth, temperate deciduous forest. Canadian Journal of Botany 78 (2): 181 – 192. doi: 10.1139/b99-176.

21. Magurran AE (1988) Ecological diversity and its measurement. New York, Chapman and Hall. doi: 10.1007/978-94-015-7358-0.

22. Bossuyt B, Hermy H (2001) Influence of land use history on seed banks in European temperate forest ecosystems: A review. Ecography 24 (2): 225 – 238. doi: 10.1034/j.1600-0587.2001.240213.x.

23. Decoq G, Valentin B, Toussaint B et al. (2004) Soil seed bank composition and diversity in a managed temperate deciduous forest. Biodiversity and Conservation 13 (13): 2485 – 2509. doi: 10.1023/B:BIOC.0000048454.08438.c6.

24. Díaz-Villa MD, Maraño T, Arroyo J, Garrido B (2003) Soil seed bank and floristic diversity in a forest-grassland mosaic in southern Spain. Journal of Vegetation Science 14 (5): 701 – 709. doi: 10.1111/j.1654-1103.2003.tb02202.x.
25. Godefroid S, Phartyal SS, Koedam N (2006) Depth distribution and composition of seed banks under different tree layers in a managed temperate forest ecosystem. Acta Oecologica 29 (3): 283-292. doi:10.1016/j.actao.2005.11.005.

26. Chaideftou E, Thanos CA, Bergmeier E et al. (2009) Seed bank composition and above-ground vegetation in response to grazing in sub-Mediterranean oak forests (NW Greece). Forest Ecology 201: 255–265. doi: 10.1007/s11258-008-9548-1.

27. Gioria M, Jaroslík V, Pyšek P (2014) Impact of invasive alien plants on the soil seed bank: Emerging patterns. Perspectives in Plant Ecology, Evolution and Systematics 16 (3): 132–142. doi: 10.1016/j.ppees.2014.03.003.

28. Gioria M, Pyšek P (2016) The Legacy of plant invasions: Changes in the soil seed bank of invaded plant communities. BioScience 66 (1): 40–53. doi: 10.1093/biosci/biv165.
### Appendix 1

**Table 3. List of plant species composing the aboveground vegetation of Mt. Nyungcung and Mt. Kapur**

| Species                          | Family         | Mt. Nyungcung | Mt. Kapur |
|----------------------------------|----------------|---------------|-----------|
| Actinodaphne macrophylla         | Lauraceae      | -             | 5         |
| Aglaia elliptica                 | Meliaceae      | -             | 1         |
| Alchornea rugosa                 | Euphorbiaceae  | -             | 44        |
| Allophylus cobbe                 | Sapindaceae    | 1             | 6         |
| Alpinia galanga                  | Zingiberaceae  | 2             | -         |
| Alstonia scholaris               | Apocynaceae    | 8             | -         |
| Antidesma montanum               | Phyllanthaceae | 29            | 15        |
| Arachnis sp.                     | Orchidaceae    | -             | 1         |
| Arcangelisia flava               | Menispermaceae | 4             | -         |
| Artocarpus heterophyllus         | Moraceae       | 2             | -         |
| Arytera littoralis               | Sapindaceae    | -             | 50        |
| Bauhinia championii              | Leguminosae    | -             | 18        |
| Bradelia tomentosa               | Phyllanthaceae | -             | 12        |
| Brucea javanica                  | Simaroubaceae  | 1             | -         |
| Buchanania arborescens           | Anacardiaceae  | 4             | 12        |
| Calliandra calothyrsus           | Leguminosae    | -             | 33        |
| Calophyllum soulatri             | Clusiaceae     | -             | 1         |
| Canthium horridum                | Rubiaceae      | 2             | -         |
| Carallia brachiata               | Rhizophoraceae | 1             | -         |
| Cecropia peltata                 | Urticaceae     | -             | 7         |
| Centrosema pubescens             | Leguminosae    | -             | 7         |
| Chrysophyllum flexuosum          | Sapotaceae     | 19            | -         |
| Cinnamomum sintoc                | Lauraceae      | 2             | -         |
| Clausena excavata                | Rutaceae       | -             | 37        |
| Cleistocalyx sp.                 | Myrtaceae      | 1             | -         |
| Coffea canephora                 | Rubiaceae      | 1             | -         |
| Coffea liberica                  | Rubiaceae      | 47            | -         |
| Combretum latifolium             | Combretaceae   | -             | 2         |
| Croton tiglium                   | Euphorbiaceae  | 1             | -         |
| Cryptocarya sp.                  | Lauraceae      | 1             | 2         |
| Curculigo ohioides               | Hypoxidaceae   | 3             | -         |
| Cyperus rotundus                 | Cyperaceae     | 7             | -         |
| Daemomorops sp.                  | Arecales       | 3             | -         |
| Dianella sp.                     | Liliaceae      | 2             | -         |
| Dioscorea hispida                | Dioscoreaceae  | 9             | -         |
| Dracaena angustifolia            | Asparagaceae   | 1             | -         |
| Dracaena eliptica                | Asparagaceae   | 9             | -         |
| Species                  | Family            | Mt. Nyungcing | Mt. Kapur |
|-------------------------|-------------------|---------------|-----------|
| Dracaena surculosa      | Asparagaceae      | 1             | -         |
| Elaeocarpus floribundus| Elaeocarpaceae    | 3             | -         |
| Erythroxylum cuneatum   | Erythroxylaceae   | 4             | -         |
| Ficus fistulosa         | Moraceae          | -             | 6         |
| Ficus geocarpa          | Moraceae          | -             | 5         |
| Ficus hirta             | Moraceae          | 1             | -         |
| Ficus montana           | Moraceae          | 1             | -         |
| Ficus septica           | Moraceae          | -             | 5         |
| Flacourtia rukam        | Salicaceae        | 1             | -         |
| Flagellaria indica      | Flagellariaceae   | 1             | -         |
| Garcinia celeba         | Clusiaceae        | 9             | -         |
| Garcinia parvillora     | Clusiaceae        | 2             | -         |
| Glochidion macrocarpum  | Phyllanthaceae    | -             | 1         |
| Glochidion philippicum  | Phyllanthaceae    | -             | 2         |
| Glochidion rubrum       | Phyllanthaceae    | -             | 1         |
| Glycosmis pentaphylla   | Rutaceae          | -             | 1         |
| Gnetum cuspidatum       | Gnetaceae         | 3             | -         |
| Gnetum gnemon           | Gnetaceae         | 2             | -         |
| Guioa diplopetala       | Sapindaceae       | 18            | -         |
| Hiptage benghalensis    | Malpighiaceae     | -             | 4         |
| Ixora javanica          | Rubiaceae         | 9             | 12        |
| Lantana camara          | Verbenaceae       | 1             | -         |
| Lepisanthes rubiginosa  | Sapindaceae       | -             | 2         |
| Litsea glutinosa        | Lauraceae         | -             | 1         |
| Litsea umbellata        | Lauraceae         | -             | 2         |
| Macaranga rhizinoides   | Euphorbiaceae     | 3             | 8         |
| Macaranga tanarius      | Euphorbiaceae     | 2             | -         |
| Mallotus floribundus    | Euphorbiaceae     | 1             | 46        |
| Melastoma malabthricum  | Melastomataceae   | 2             | -         |
| Melicope lunu-ankenda   | Rutaceae          | -             | 1         |
| Microcos hirsuta        | Malvaceae         | 12            | -         |
| Mucuna sp.              | Leguminosae       | 1             | -         |
| Nauclea sp.             | Rubiaceae         | -             | 2         |
| Pandanus sp.            | Pandanaceae       | 21            | -         |
| Parameria laevigata     | Apocynaceae       | -             | 1         |
| Piper aduncum           | Piperaceae        | -             | 3         |
| Polycias diversifolia   | Araliaceae        | 7             | -         |
| Pothos junghuhnii       | Araceae           | 1             | -         |
| Prrospermum javanicum   | Malvaceae         | -             | 1         |
| Radermachera gigantea   | Bignoniaceae      | 6             | -         |
| Species                  | Family            | Number of Plants |
|-------------------------|-------------------|------------------|
| *Rothmannia longiflora* | Rubiaceae         | -                |
| *Sauropus androgynus*   | Phyllanthaceae    | 12               |
| *Selaginella sp.*       | Selaginellaceae   | 5                |
| *Smilax leucophylla*    | Smilacaceae       | -                |
| *Stachytarpheta indica* | Verbenaceae       | 19               |
| *Strophioblachia fimbriaclyx* | Euphorbiaceae | 63               |
| *Syzygium acuminatissimum* | Myrtaceae    | 9                |
| *Syzygium lineatum*     | Myrtaceae         | 2                |
| *Syzygium pycnanthum*   | Myrtaceae         | 2                |
| *Syzygium racemosum*    | Myrtaceae         | 2                |
| *Tetracera scandens*    | Dilleniaceae      | 2                |
| *Tristanopsis sp.*      | Myrtaceae         | 27               |
| *Uncaria gambir*        | Rubiaceae         | 2                |
| *Uvaria concava*        | Annonaceae        | 1                |
| *Vitex pinnata*         | Lamiaceae         | 2                |
| *Voacanga grandifolia*  | Apocynaceae       | -                |
| *Weinmannia fraxinea*   | Cunoniaceae       | -                |
### Table 4. List of plant species in the seed bank of Mt. Nyungcung and Mt. Kapur

| Species                        | Family                  | Number of Plants | Mt. Nyungcung | Mt. Kapur |
|--------------------------------|-------------------------|------------------|---------------|-----------|
| Abrus precatorius              | Leguminosae             | 1                | -             | -         |
| Aerva javanica                 | Amaranthaceae           | 10               | 3             | -         |
| Ageratum conyzoides            | Compositae              | 1                | -             | -         |
| Allophylus cobbe               | Sapindaceae             | -                | 1             | -         |
| Alpinia galanga                | Zingiberaceae           | 3                | -             | -         |
| Alstonia scholaris             | Apocynaceae             | 2                | -             | -         |
| Amorphophallus variabilis      | Araceae                 | 1                | -             | -         |
| Antidesma montanum             | Phyllanthaceae          | 32               | 17            |           |
| Axonopus compressus            | Poaceae                 | 1                | 2             |           |
| Bredelia tomentosa             | Phyllanthaceae          | -                | 1             | -         |
| Bruea javanica                 | Simaroubaceae           | 2                | 1             |           |
| Caladium sp.                   | Araceae                 | 1                | -             | -         |
| Calliandra calothyrsus         | Leguminosae             | -                | 1             | -         |
| Callicarpa sp.                 | Lamiaceae               | 3                | -             | -         |
| Carallia brachiata             | Rhizophoraceae          | 20               | -             | -         |
| Carica papaya                  | Caricaceae              | -                | 1             | -         |
| Cecropia peltata               | Urticaceae              | 44               | 646           |           |
| Centrotheca lappacea           | Poaceae                 | 115              | 64            |           |
| Centrosera pubescens           | Leguminosae             | 70               | 4             |           |
| Chlorophyllum orchidastrum     | Asparagaceae            | -                | 1             | -         |
| Chromolaena odorata            | Compositae              | 13               | 14            |           |
| Chrysophyllum flexuosum        | Sapotaceae              | 40               | -             | -         |
| Clausena excavata              | Rutaceae                | 1                | -             | -         |
| Clidemia hirta                 | Melastomataceae         | 589              | 40            |           |
| Coffea liberica                | Rubiaceae               | 1                | -             | -         |
| Combretum latifolium           | Combretaceae            | -                | 2             |           |
| Costus spiralis                | Costaceae               | 5                | -             | -         |
| Cratoxylum formosum            | Hypericaceae            | 22               | -             | -         |
| Croton tiglium                 | Euphorbiaceae           | 6                | -             | -         |
| Curculigo ochioides            | Hypoxidaceae            | 7                | -             | -         |
| Cyperus rotundus               | Cyperaceae              | 6                | -             | -         |
| Cyperus sp.                    | Cyperaceae              | 1                | -             | -         |
| Dianella sp.                   | Liliaceae               | 2                | -             | -         |
| Digitaria sp.                  | Poaceae                 | 2                | 1             |           |
| Dillenia obovata               | Dilleniaceae            | 1                | -             | -         |
| Dioscorea hispida              | Dioscoreaceae           | 15               | -             | -         |
| Embelia ribes                  | Primulaceae             | 207              | -             | -         |
| Erythroxylum cuneatum          | Erythroxylaceae         | 3                | 76            |           |
| Species          | Family       | Number of Plants | Mt. Nyungcung | Mt. Kapur |
|------------------|--------------|------------------|--------------|-----------|
| Ficus annulata   | Moraceae     | 5                |             |           |
| Ficus coronata   | Moraceae     | 1                |             |           |
| Ficus deltoidea  | Moraceae     | 4                |             |           |
| Ficus hirta      | Moraceae     | 3                |             |           |
| Ficus palmata    | Moraceae     | 1                | 2           |           |
| Ficus sagitata   | Moraceae     | 2                |             |           |
| Ficus septica    | Moraceae     | -                | 1           |           |
| Ficus uncinata   | Moraceae     | -                | 1           |           |
| Galinsoga parviflora | Compositae  | 28               | 2           |           |
| Gmelina arborea  | Lamiaceae    | 2                |             |           |
| Hibiscus calyphyllus | Malvaceae   | -                | 1           |           |
| Hibiscus macrophyllus | Malvaceae | 11               | 9           |           |
| Hiptage benghalensis | Malpighiaceae | 1           | 9           |           |
| Ischaemum timorense | Poaceae     | 11               | 12          |           |
| Lantana camara   | Verbenaceae  | 5                |             |           |
| Laportea aestuans | Urticaceae  | 4                | 6           |           |
| Lepidaploa obtusifolia | Compositae | 2                |             |           |
| Leucaena leucocephala | Leguminosae | -                | 7           |           |
| Macaranga rhizinoides | Euphorbiaceae | 23               | 9           |           |
| Macaranga tanarius | Euphorbiaceae | 27               | 13          |           |
| Mallotus floribundus | Euphorbiaceae | 11               | 14          |           |
| Melastoma malabathricum | Melastomataceae | 586              | -           |           |
| Melicope lunu-ankenda | Rutaceae       | 47               |             |           |
| Mikania micrantha | Compositae  | 7                | 6           |           |
| Momordica charantia | Cucurbitaceae | 1               |             |           |
| Mussaenda acuminata | Rubiaceae       | 323              | 1           |           |
| Oxalis barrelieri | Oxalidaceae  | -                | 2           |           |
| Oxalis corniculata | Oxalidaceae  | 2                | 2           |           |
| Oxalis sp.       | Oxalidaceae  | -                | 1           |           |
| Passiflora foetida | Passifloraceae | 1               | 1           |           |
| Peperomia pellucida | Piperaceae     | 66               | 3           |           |
| Physalis minima  | Solanaceae   | -                | 3           |           |
| Piper aduncum    | Piperaceae   | 3                | 69          |           |
| Rhynchospora colorata | Cyperaceae     | 2                |             |           |
| Rostellularia sundana | Acanthaceae   | 2                | 1           |           |
| Rotheca serrata  | Lamiaceae    | 2                | 2           |           |
| Rubus pubescens  | Rosaceae     | 10               |             |           |
| Sauropus androgynus | Phyllanthaceae | 1               |             |           |
| Scirpodendron ghaeri | Cyperaceae    | 3                |             |           |
| Species                  | Family         | Mt. Nyungcung | Mt. Kapur |
|--------------------------|----------------|---------------|-----------|
| Scleria Sumatrensis      | Cyperaceae     | 2             | 2         |
| Selaginella sp.          | Selaginella    | 29            | 110       |
| Sida rhombifolia         | Malvaceae      | 1             | -         |
| Solanum americanum       | Solanaceae     | 16            | 6         |
| Solanum diphylleum       | Solanaceae     | -             | 1         |
| Solanum torvum           | Solanaceae     | 69            | 6         |
| Spermacoce laevis        | Rubiaceae      | 13            | 2         |
| Spigelia anthelmia       | Loganiaceae    | 2             | 6         |
| Stachytarpheta indica    | Verbenaceae    | 2             | 73        |
| Tetracera scandens       | Dilleniaceae   | 2             | -         |
| Torenia violacea         | Linderniaceae  | 10            | -         |
| Trema orientalis         | Cannabaceae    | 19            | -         |
| Uricia lagopodoides      | Leguminosae    | 1             | -         |
| Urochloa glumaris        | Poaceae        | 1             | -         |
| Vitex pinnata            | Lamiaceae      | 5             | -         |
| Xanthosoma sp.           | Araceae        | 5             | 22        |