The Influence of Fire on Biomass Weight of Herbs in Lowland and Highland

Suhadi¹*, Sueb¹, Sonny Wedhanto²

¹Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang 5 Malang 65145, Indonesia
²Department of Civil Engineering, Faculty of Engineering, Universitas Negeri Malang, Jl. Semarang 5 Malang 65145, Indonesia.

*Corresponding author’s email: suhadi@um.ac.id

Abstract. The objectives of this study were to determine the differences of biomass in burning and non-burning sites in upland and lowland areas, to know the types of non-burning plants in burning locations, and to classify fast burning plants in burning sites. The study was done in Baluran National Park representing lowland and Ijen Crater Natural Tourism Park representing highland. The size of the plot is 1×1 m², and the repeated measures are four replications. The conclusions are that fire in lowland savanna decreased herb biomass, Tectona grandis Linn.f forest fire slightly decreased herb biomass, and fire in highland savanna increased herb soil biomass.

Keywords: Fire, herb biomass, lowland, highland.

1. Introduction
Forest fire frequently sweep over Indonesia. Reportedly, fire hit more than 100,000 million hectares of forests and savanna from June until October 2015. It is forecasted to cause severe economic loss of more than US $15 billion that is equivalent to IDR 196 trillion. The fire took place in situ areas of Sumatera, Kalimantan, and Java. Another unfavorable impact of fire is the distribution of carbon dioxide emissions. Forest fire in 1997 contributed 2.6 billion tonnes of carbon dioxide emissions to the six billion tonnes total carbon emissions all over the world in the same year [1].

On the other hand, fire can be a tool in the management of savanna ecosystems. When used, the fire has more prolonged effects on vegetation. Fire prevents forest regeneration, and control the growow of shrubs and worms that feed on growing grasses. Fire is the fastest way to control overgrown shrubs. Savanna fire set by people in the early rainy season is one of the ways to decrease bigger fire risk in the future[2]. In Brazil, fire control on weeds increases pH, Ca, Mg, and Na exchange, decreases Al but the P decreases in the first up to the fourth year. Oxisol with a combination of fire and P fertilizer can improve the soil quality [3].

Forest fire smoke on moss land contains harmful organic carbons. There is 80% N composition in the air, and the rests are CO₂, N₂O, NOx, and CO gases. There are other elements which are more dangerous, i.e., numerous heavy metals presenting a very smooth shape. The particle sizes from 2.5 up to 0.1 microns like Cr, Cd, and Ni [4].
Ijen Crater National Park is located in Banyuwangi and Bondowoso. It covers an area divided into a 92-hectare National Park and 2,468-hectare nature conservation. This area is a transition of Mount Rain Forest at an altitude of 1,000 - 2,500 from the sea level to Sub-Alpine Rain Forest altitude of 2,500 - 4,000 m above sea level. The dominant species are Compositae and Ericaceae Families. In the Sub-Alpine rainforest were found montane dry forest and shrubs. This area often burns in dry season since it is dominated by pines (Casuarina junghuhniana Miq) and shrubs.

Baluran National Park covers an area of 25,000 hectares with a 40-km coastline. In the middle of Baluran National Park, there is an inactive Baluran mountain with a peak of 900-1247 m above sea level. The topography varies from flat to 60° slope. Flat until slope areas are found along the beach to the foot of Mount Baluran. Specific forest ecosystems on the island of Java dominate the savanna ecosystem. The forest is made by savanna that occupies 40%, 20% teak forests, and the remaining are mangrove, coastal, swamp, and evergreen forest. There are 444 species of flora and 26 species of mammals and 147 species of birds. It burns every year with the fire concentration mainly in savanna and the Tectona grandis Linn.f. forest [5]. The Baluran National Park houses 15 dominant species of Polytrias praemosa and Axonopus compressus (Sw.) P.Beauv., while the savanna forest consists of 58.46% Gramineae; 24.21% Fabaceae; 2.56% Euphorbiaceae; 8.86% Malvaceae and 5.91% Cyperaceae [6]. Acacia nilotica (L.) Willd. ex Delile at Baluran National Park is used for very high firebreaks due to its rapid growth inhibiting the growth of herbs in the savanna [7].

Forest fires decrease soil nutrients in soil surface in number and quality so the growth and development of plants will be hampered. Similarly, heavy metals especially Hg will accumulate in soil and may accumulate in animal tissues, plants and contaminate water areas around the fire. There is a fire in the areas of Baluran National Park and Ijen Crater Park in almost every 3-5 years yet the medium of fire and its cause are indeed unidentified. The objectives of this study were to determine the differences of biomass in burning and non-burning sites in upland and lowland areas, to identify the types of plants in burning and non-burning locations, and to know fast growing plants in burning locations.

2. Experimental Methods
The lowland sampling locations are Briu Savannah and teak forests of Baluran National Park of between 5-20 meter altitudes above sea level, while the highland sampling places are Ijen Crater Natural Tourism Park, which is between 2500-3000 meters above sea level. The samples of lowland are taken at Baluran National Park, and the samples of highland are taken at Ijen Crater Natural Tourism Park. The method used is the quadratic method. The points of the sample point lay on the transect path following the contour line. The distance between plots are 10 meters and 50 meters between transects. The size of the plot is 1×1 m², and the measures are repeated in ten replications.

3. Results and Discussion
At Briu Savannah, the biomass of Aeschynomene elegans Schlecht&Cham in the fire area reached 15.96 gram.m⁻² and 13.25 gram.m⁻² in non-burning area. Besides that were found Genus Aeschynomene, herbaceous perennial with a strong taproot, pubescent stems (sometimes hispidulous) to 1 m long and with 1 - 3 mm in diameter, leaves 5-7 (-9) foliolate, leaflets obovate to elliptical about 6 - 12 mm long, and 2.5 - 4 mm wide, pubescent on both surfaces. Also, there was inflorescence comprising 1 or 2 yellow flowers with a standard 7 - 9 mm long. Next also found a pod curved, 15 - 30 mm long comprising 4 - 8 articles, dehiscing along the scalloped suture at maturity. Finally, there were seeds of 2 mm long, and 1.5 mm wide, commonly dark brown, but varying from light yellowish-brown to almost black; c. 370,000-450,000 seeds/kg. Plants are morphologically similar to A. elegans and A. brevifolia [8,9]. At burned and unburned areas, the growth of Aeschynomene elegans Schlecht & Cham is so rapid that its biomass in one season occurs in competition over other plants, especially in the lowlands, whereas a slow growth was found in the non-burning areas at the highlands. In their research [3], Serrao et. al. expressed that fire would increase the pH, Ca, Mg, Na exchange.
Table 1. Lowlands (Tectona grandis Linn.f Forest at Baluran National Park)

| No Fire Mean of biomass weight (gram.m⁻²) | Transition Mean of biomass weight (gram.m⁻²) | Fire Mean of biomass weight (gram.m⁻²) |
|------------------------------------------|--------------------------------------------|-------------------------------------|
| 49.09                                    | 12.61                                      | 44.57                               |
| The dominant plant
  - Mimosa invisa Mart. ex Colla
  - Themeda arguens (L.) Hack
  - Themeda arguens (L.) Hack

Table 2. Burning and non-burning plants biomass in the lowlands

| No | Species                          | Burning (gram.m⁻²) | Non Burning (gram.m⁻²) |
|----|----------------------------------|--------------------|------------------------|
| 1  | Aeschynome elegans Schlecht & Cham | 15.96              | 13.25                  |
| 2  | Apluda mutica L                  | 0.79               | 0.00                   |
| 3  | Blumea balsamifera (L.) DC       | 1.68               | 3.03                   |
| 4  | Calopogonium mucunoides Desv     | 0.54               | 6.84                   |
| 5  | Commelina diffusa Burm.f         | 0.54               | 0.00                   |
| 6  | Desmodium gangeticum (L.) DC    | 0.65               | 0.00                   |
| 7  | Elephantopos scaber L           | 0.56               | 0.00                   |
| 8  | Eranthemum capense L            | 0.65               | 0.00                   |
| 9  | Eudalia amaura (Buace) Ohwi      | 10.08              | 12.23                  |
| 10 | Euphorbia hirta L               | 0.52               | 0.00                   |
| 11 | Imperata cylindrica (L.) P.Beauv.| 0.00               | 0.93                   |
| 12 | Mimosa invisa Mart. Ex Colla    | 3.18               | 12.84                  |
| 13 | Moghania strobilifera ((L.)J.St.-Hil.| 2.40          | 0.00                   |
| 14 | Oplismenus burmani (Retz.) Beauv.| 1.84              | 0.00                   |
| 15 | Passiflora foetida L            | 0.00               | 0.79                   |
| 16 | Pennisetum purpureum Schumach   | 0.23               | 1.54                   |
| 17 | Cyperus rotundus L              | 0.00               | 0.93                   |
| 18 | Schlerachne punctata R. Br      | 2.84               | 5.39                   |
| 19 | Sida rhombifolia L              | 0.81               | 0.00                   |
| 20 | Sorghum nitidum (Vahl) Pers     | 0.70               | 9.87                   |
| 21 | Synebrela nodiflora (L.) Gaertn | 0.52               | 0.00                   |
| 22 | Themeda arguens (L.) Hook       | 8.81               | 13.69                  |
| 23 | Urvia lagopoidoides (L.) Desv. Ex DC | 0.79            | 3.17                   |
|    | Total                            | 54.12              | 84.51                  |

In research [10] and [11], the biological characteristics that make Imperata cylindrica (L.) P.Beauv. very successful were reviewed. The weed shows wide genetic variability that allows it to adapt to a wide range of ecological and management conditions. It possesses five taxonomic varieties with var. major in Asia and var. Africana in West African being the most serious. Imperata cylindrica (L.) P.Beauv. breed through sexual reproduction of seeds and vegetative by rhizomes. It flowers rapidly after experiencing stress from fire, absorbing soil nutrients high, and drought resistant. It produced 3000 seeds, without dormancy period, and with more than 1 year life [12]. In aggressive and invasive natures, rhizomes that usually concentrate above 15-20 cm above ground can survive for a long period [13]. Rhizome has a high regenerative ability because of the numerous buds that readily sprout into new shoots after fragmentation by tillage or any other forms of disturbances. Rhizome is resistant to fire because of its deep soil burial. Deep burial also makes Imperata cylindrica (L.) P.Beauv. very resistant to most control strategies [13]. The ability of rhizome fragments to regenerate decreases with a reduction in length of rhizome segment. Longer rhizomes have better chances of sprouting because they have more carbohydrate reserves than short fragmented rhizomes [14].
### Table 3. The biomass of burned and unburned plants in the highlands

| No | Species                                      | Burning (gram.m⁻²) | Non burning (gram.m⁻²) |
|----|---------------------------------------------|--------------------|------------------------|
| 1  | *Aeschynomene elegans* Schlecht& Cham       | 14.09              | 0.50                   |
| 2  | *Ageratum conyoides* L                      | 0.00               | 0.34                   |
| 3  | *Blume lacera* (Burm.f.) DC                 | 16.08              | 0.50                   |
| 4  | *Carex bohemica* L                         | 5.38               | 56.08                  |
| 5  | *Centella asiatica* (L) Urban               | 0.00               | 29.68                  |
| 6  | *Cyperus* sp                                | 0.00               | 2.80                   |
| 7  | *Desmodium hirtum* Guill. &Perr             | 17.93              | 25.59                  |
| 8  | *Desmodium paniculatum* (L.) DC.            | 23.89              | 54.23                  |
| 9  | *Dryopteris* sp                             | 65.20              | 0.00                   |
| 10 | *Equisetum ramosissimium* Desf              | 25.30              | 0.00                   |
| 11 | *Eragrostis brownii* (Kunth) Nees           | 16.63              | 4.96                   |
| 12 | *Eragrostis cilianensis* (All.) Vign ex Janchen | 6.96          | 7.15                   |
| 13 | *Eupatorium inulifolium* Kunth              | 25.92              | 0.03                   |
| 14 | *Hedychium roxburghii* (Blume) Kuntze       | 2.57               | 0.05                   |
| 15 | *Imperata cylindrica* (L.) P.Beauv.         | 512.97             | 52.36                  |
| 16 | *Ipomoea* sp                                | 2.57               | 0.00                   |
| 17 | *Ipomoea triflora* L.                       | 2.57               | 0.00                   |
| 18 | *Oplismenus compositus* (L.) P. Beauv       | 0.00               | 38.30                  |
| 19 | *Oxalis corniculata* L.                     | 0.00               | 5.25                   |
| 20 | *Phyllanthus niruri* L.                     | 2.64               | 0.00                   |
| 21 | *Plantathera susannae* (L.) Lindl           | 2.57               | 0.05                   |
| 22 | *Polygonum* sp                              | 4.01               | 0.00                   |
| 23 | *Pteris* sp                                 | 0.00               | 7.89                   |
| 24 | *Rubus niveus* Thunb.                       | 2.57               | 0.00                   |
| 25 | *Sorghum nitidum* (Vahl) Pers               | 222.99             | 239.01                 |
| 26 | *Spilanthes* sp                             | 5.96               | 0.11                   |
| 27 | *Vernonia cinerea* (L.) Less                | 0.00               | 1.16                   |
| 28 | *Debregeasia longifolia* (Burn.f) Wedd      | 0.00               | 3.85                   |
|    | **Total**                                   | **978.80**         | **529.88**             |

*Imperata cylindrica* (L.) P.Beauv. is a plant that has a rapid growth of biomass at fire area reaching 512.97 grams.m⁻² on the plateau. Savanna which is dominated by this plant will accelerate the rate of natural succession to the secondary forest that will ultimately shade and suppress the weeds. In order to prevent fire, the growth of *Imperata cylindrica* (L.) P.Beauv. must be suppressed as it causes the risk of fire in the next year [15]. Fire separation by removing leaves, soil processing, and combustion in a controlled manner is necessary to prevent land fires[16].

Biomass in the location of Savana Briu National Park of Baluran is concentrated in lowland areas that have not experienced heavy fire reaching 84.51 gram.m⁻² while it reached 54.12 gram.m⁻² at the location of the heavy fire and a biomass of 40.58 grams.m⁻² in weight transition area. The dominating plants are *Aeschynomene elegans* Schlecht&Cham and *Themeda arguens* (L.) Hack. These types of plants are commonly found in the area of ample water. In the state of lack of water, they were quickly dried up. Therefore, they are easy to burn and grow very fast in the open state. Flammable herbs have a biomass weight of 0.4 - 1.3 gram.m⁻² [17].

The *Tectona grandis* Linn.f forest in flammable areas has been dominated by the type *Themeda arguens* (L.) Hack. The area that has not burned is dominated by *Mimosa invisa* Mart. ex Colla. This species is easily depressed by water and quickly dries in the dry season. The *Tectona grandis* Linn.f forest area includes deciduous forest type. Deciduous teak leaves add soil surface biomass, so the area is flammable. Fire will increase the pH, Ca, Mg, Na exchange [3] so it will accelerate the growth of
weeds in the rainy season. Furthermore, Ijen Tourism Area has an altitude of 2500-4000 m above sea level. Both burned and unburned areas are dominated by Imperata cylindrica (L.) P.Beauv. dan Sorghum nitidum (Vahl) Press. In severe burning areas, the biomass reached 978.80 grams.m$^{-2}$. High herbaceous biomass is prone to fire. Imperata cylindrica (L.) P.Beauv. and Sorghum nitidum (Vahl) Press species are easily depressed by water.

4. Conclusion

Based on the results and discussion, it can be concluded that fires in lowland savanna decrease herb biomass. Tectona grandis Linn.f. forest fire decreases little herb biomass, and fires in highland savanna increase herb soil biomass. Imperata cylindrica (L.) P.Beauv. in the areas of highland fires have rapid growth.

Acknowledgments

Thanks to the Directorate General of Higher Education of the Ministry of Research of Technology and Higher Education and LP2M Universitas Negeri Malang who financed this research.

References

[1] Badan Pengendalian Dampak Lingkungan, dan Canadian International Development Agency (CIDA) - Collaborative Environmental Project in Indonesia (CEPI). Data 1997/1998 dari Asian Development Bank (ADB) . Departemen Kehutanan (2016). 1997.
[2] MacKinnon JR, IUCN Commission on National Parks and Protected Areas., International Union for Conservation of Nature and Natural Resources., United Nations Environment Programme., Global Environmental Monitoring System., World Congress on National Parks (1982 : Bali I. Managing protected areas in the tropics. International Union for Conservation of Nature and Natural Resources; 1986.
[3] Serrao, E.A.S., I.C. Falesi JBDV &J. FTN. Productividad de praderas cultivadas en suelos de baja fertilidad de la Amazonia del Brasil. Prod Pastos En Suelos Acidos Los Trop 1978;CIAT, Cali:211–43.
[4] Tempo. Ini Komposisi Berbahaya Kabut Asap Kebakaran Hutan - Nasional Tempo.co 2015. https://nasional.tempo.co/read/714629/ini-komposisi-berbahaya-kabut-asap-kebakaran-hutan (accessed August 3, 2018).
[5] Baluran BTN. Review Rencana Pengelolaan Taman Nasional Baluran. Proyek Pengembangan Taman Nasional Baluran Dengan Dana Reboisasi Tahun Anggaran 1994/1995. p. 20. 1995.
[6] Raharjo Y. Komposisi, Kelimpahan dan Diversitas Komunitas Tumbuhan Hutan Savana di Taman Nasional Baluran Banyuwangi. Universitas Brawijaya Malang; 1995.
[7] Alikodra HS. Tanaman Eksotik Akasia (Acacia Nilotica) dan Masalahnya bagi Ekosistem Savanna di Taman Nasional Baluran. Duta Rimba 1987;13:30–4.
[8] Cook B. Aeschynomene falcata (Poiret) DC. In : ’t Mannetje, L. and Jones, (R.M. (eds) Plant Resources of South-East Asia No.4 Forages. Pudoc Scientific Publishers, Wageningen The Netherlands; 1992.
[9] CLEMENTS R, Grasslands GB-T, 2000 undefined. Sown pastures in subcoastal south-eastern Queensland: pasture composition, legume persistence and cattle liveweight gain over 10 years. TropicalgrasslandsInfo n.d.
[10] Townsend J. Imperata cylindrica and its control. Weed Abstr 1991;40: 457-46.
[11] Terry PJ, Adjers G, Akobundu IO, Anoka AU, Drilling ME, Tjitrosemito S, et al. Herbicides and mechanical control of Imperata cylindrica as a first step in grassland rehabilitation. Agrofor Syst 1996;36:151–79. doi:10.1007/BF00142872.
[12] Santiago A. Studies on the autecology of I. cylindrical (L.) Beauv. Proc 9th Int Grasslands Congr Sao Paulo, Brazil 1965;pp. 499-50.
[13] Ivens GW. Imperata cylindrica (L.) Beauv. in West African agriculture. Proc BIOTROP Work Alang-Alang, Bogor, 27-29 July 1976 1980:149–56.
[14] Ivens GW. Studies on Imperata cylindrica (L.) Beauv. and Eupatorium odoratum L. Weed Research Project R 2552, 1971-1973. Stud Imp Cylind Beauv Eupatorium Odoratum L Weed Res Proj R 2552, 1971-1973 1975.

[15] Anonim. Imperata management for smallholders: an extensionist’s guide to rational Imperata management for smallholders 1996.

[16] Wibowo A, Suharti M, Sagala APS, Hibani H, Van Noordwijk M. Fire management on Imperata grasslands as part of agroforestry development in Indonesia. Agrofor Syst 1996;36:203–17. doi:10.1007/BF00142874.

[17] Reis SM, de Oliveira EA, Elias F, Gomes L, Morandi PS, Marimon BS, et al. Resistance to fire and the resilience of the woody vegetation of the “Cerradão” in the “Cerrado”–Amazon transition zone. Brazilian J Bot 2017;40:193–201. doi:10.1007/s40415-016-0336-1.