Secondary succession after fire in *Imperata* grasslands of East Kalimantan, Indonesia

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Abstract
We studied an early succession in *Imperata* grasslands in East Kalimantan, Indonesia, using plots that last burned 3 years, 4 years and 9 years previously on, secondary and primary forest. The species coverage data were analyzed using CANOCO software. While *Imperata* decreases, the average percentage of shrubs and young trees clearly increases with time. In the burned plots, *Melastoma malabathricum*, *Eupatorium inulaefolium, Ficus* sp., and *Vitex pinnata L.* strongly increase with the age of regeneration, but these species were rare in the secondary forest. Soils with more than 50% sand had a slower development towards secondary forest. The number of species was lower on the sandy soils, which showed a stronger increase with time of *Pteridium aquilinum* L.. This fern slows down subsequent vegetation development. Canonical correspondence analysis (CCA) of the environmental gradient and vegetation showed that pH, bulk density, sand and clay are the factors influencing the distribution of species. Canonical correspondence analysis showed also that soil properties had a strong influence on vegetation composition. *Melastoma malabathricum, Vitex pinnata* L.*, Lycopodium cernum, Vernonia arborea* Buch.-Ham., *Dicranopteris linearis* are all species associated with high levels of exchangeable Al and low pH.

Key Words
Early succession, Imperata grasslands, Pteridium aquilinum, soil properties.

Introduction
Kalimantan, the Indonesian part of Borneo, covers about 73% of the land area of the island, and has one of the important tropical forests in the world. Nowadays, large areas of primary forest in Kalimantan have been changed into secondary forest, oil palm plantation, timber estate plantation, slash-and-burn agriculture, and also grasslands such as *Imperata cylindrica.* When *Imperata* grassland are abandoned and not burned regularly, they will undergo a series of vegetation changes, a process called secondary succession. In the early phase of secondary succession, ferns, herbs, lianas and young trees (pioneer species) rapidly colonize the site. Leps (1987) mentioned that this early stage of succession influences the later stages of vegetation development, which in their turn determine the character of the secondary forest and the recovery of the original biodiversity. Soil properties also change during secondary succession. Upon burning, pH initially increases due to production of carbonates upon ashing of vegetation. Van der Kamp *et al.* (2009) described changes of soil carbon stocks under secondary succession, using the same plots as used in the present paper. The present paper describes the pathways of secondary succession in *Imperata* grasslands of East Kalimantan, Indonesia. The objectives of this study were (a) to examine how the species community develops after fire and whether different directions are observed; (b) to explore the relation between community structure and pattern and environmental gradients.

Methods
Data collection
All field data were collected in the area of Samboja Lestari (secondary succession) and Sungai Wain (primary forest) from January until April 2007. In total, 291 plots were analyzed of which 28 in Sungai Wain and 263 in Samboja Lestari. The dataset contains 19 transects with a length varying from 200 to 1000 meters. All the plots in Sungai Wain belong to a single transect. The number of plots per transect varied from 6 to 24 and distance between the plots varied from 2 to 150 meters. Vegetation was sampled in plots of 2*2 meter. The soil profiles were shallow and consisted of an A, an AB and a B horizon, to a maximum depth of 50 cm.

Data analysis and statistical methods
Changes in species distribution after last fire incidence were analyzed in spreadsheets of Microsoft Excel. For this purpose, data were transformed to percentage coverage. Canonical Correspondence Analysis (CCA) was applied to assess the relative importance of first and second major gradients of environmental variables in explaining the species distribution patterns. Eight properties of A-horizons were included in the analysis.

Results

In the whole study (BOS Samboja Lestari and Sungai Wain), 252 plant species were identified. Table 1 shows changes with time after burning of the cover of *Imperata cylindrica*, *Pteridium aquilinum*, and the percentage of shrubs and young trees. Table 1 indicates significant changes with increasing time of regeneration. After three years of regeneration, *Imperata cylindrica* had the highest average coverage; it becomes less dominant from the fourth year on. The average cover of *Pteridium aquilinum* is initially low but increases after 4 and 9 years of regeneration. Also the average percentage of shrubs and young trees clearly increases with time. In the secondary forest other tree species take over, and both *Imperata* and *Pteridium* have disappeared.

Table 1. The cover (%) of *Imperata cylindrica, Pteridium aquilinum*, and shrubs + young trees.

Regeneration time and number of observations	*Imperata cylindrica* (%)	*Pteridium aquilinum* (%)	*Shrubs and young trees* (%)
3 years (n=47)	63	10	21
4 years (n=94)	40	18	31
9 years (n=81)	18	25	44
Secondary forest (n=41)	0	0	30

Observation in the field suggested that sandy textures might influence the secondary succession. Soils with more than 50 percent of sand appear to have a slower development to secondary forest (Figure 1). Although there is little difference after 3 and 4 years of regrowth, after nine years shrubs reached higher cover percentages on less sandy soils and *Pteridium* on the sandy soils. Figure 1 show also that *Pteridium aquilinum* may induce stagnation in the regeneration of Imperata grasslands. *Pteridium aquilinum* can reach a height of 2-3 meters and casts much more shade than *Imperata* grassland. In addition, it has thick and deep rhizomes and slowly decomposable litter, which may impede germination of seeds from other species. This is consistent with Den Oden (2000), who mentioned that *Pteridium aquilinum* can induce stagnation in succession through shading, smothering, the build up of a deep ectorganic soil layer and the support of a high density of herbivore and seed-eating rodents.

Figure 2 show also that environmental variables have a strong influence on species composition. *Melastoma malabathricum, Vitex pinnata, Lycopodium cernum, Dicranopteris linearis, Syzygium lineatum, Vernonia arborea* are all associated with high concentrations of exchangeable Al and with low pH. The association of species such as *Melastoma malabathricum* with high concentrations of exchangeable Al or low pH values, was also mentioned by Watanabe and Osaki (2001) and Osaki *et al.* (2003). *Bridelia glauca,* and *Callicarpa longifolia* are associated with finer-textured soils, contrary to *Stenochlaeana palustris*, *Pteridium aquilinum* and *Spatolobus* sp., which are associated with coarser textures.

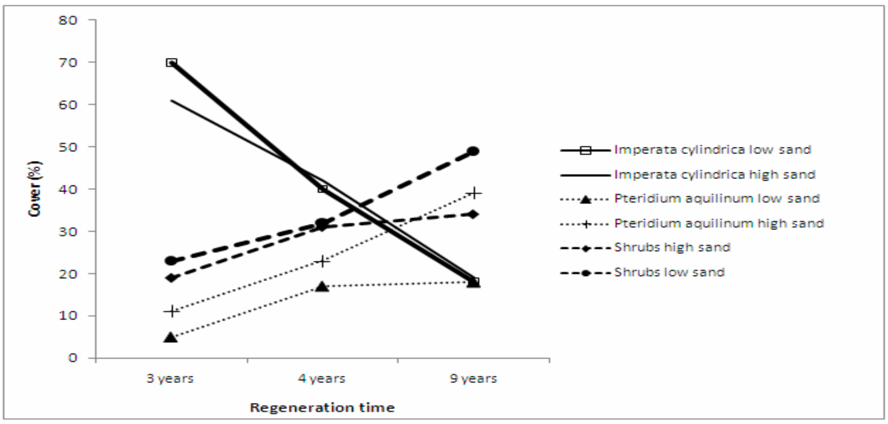

Figure 1. Cover (%) of *Imperata cyclindrica, Pteridium aquilinum* and shrubs + young trees in different phases of regeneration for high (> 50 %) and low sand content (< 50 %).

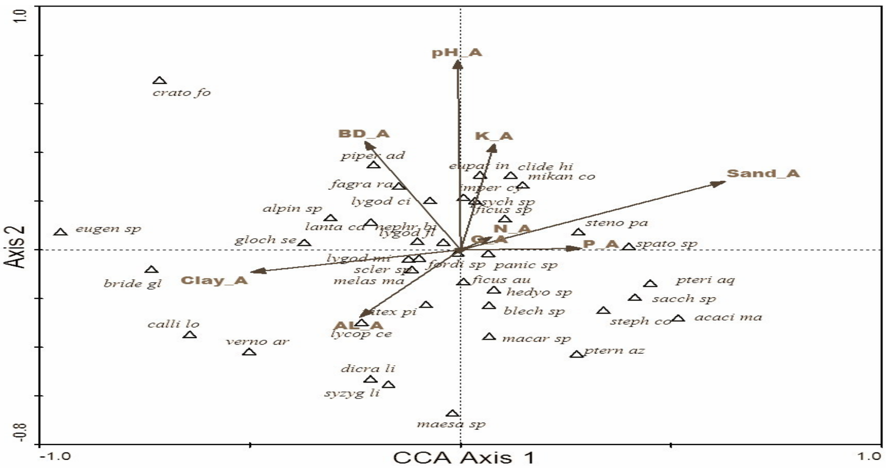

Figure 2. Plot of environmental variables and species (triangles) of *Imperata* grasslands systems (burned in 2004, 2003 and burned before 2003 plot on the first two CCA axes (only 40 species significantly abundant were analysed to CCA). Environmental variables in the A-horizon: (Clay_A=clay; AL_A=aluminium; BD_A=bulk density; K_A=Potassium; C_A= carbon percentage; N_A= Nitrogen total; P_A=Phosphor; Sand_A=sand). Variable vegetation: Acaci ma= *Acacia mangium ;* Alpin sp= *Alpinia* sp; Bride gl= *Bridelia glauca* ; Calli lo= *Callicarpa longifolia ;* Clide hi= *Clidemia hirta ;* Crato fo= *Cratoxylum formosum ;* Dicra li= *Dicranopteris linearis ;* Eugen sp =*Eugenia* sp. ; Eupat in= *Eupatorium inulaefolium ;* Fagra ra= *Fagraea racemosa ;* Ficus sp= *Ficus* sp. ; Ficus au= *Ficus aurata ;* Fordi sp= *Fordia splendidissima ;* Gloch se= *Glochidion sericeum ;* Hedyo sp= *Hedyotis* sp. ; Imper cy= *Imperata cylindrica;* Lanta ca= *Lantana camara;* Lycop ce= *Lycopodium cernum;* Lygod ci= *Lygodium circinatum;* Lygod fl= *Lygodium flexuosum;* Lygod mi= *Lygodium microphyllum;* Macar sp= *Macaranga* sp.; Maesa sp= *Maesa* sp.; Melas ma= *Melastoma malabathricum;* Mikan co= *Mikania cordata;* Nephr bi= *Nephrolepis biserrata ;* Panic sp= *Panicum* sp.; Piper ad= *Piper aduncum;* Psych sp= *Psychotria* sp.; Pteri aq= *Pteridium aquilinum;* Ptern az= *Pternandra azurea;* Sacch sp= *Saccharum spontaneum;* Scler sp= *Scleria* sp.; Spato sp= *Spatholobus* sp.; Steno pa= *Stenochlaeana palustris;* Steph co= *Stephania corymbosa;* Syzyg li= *Syzygium lineatum;* Verno ar= *Vernonia arborea;* Vitex pi= *Vitex pinnata.*

Conclusion

Imperata grasslands are not a final and stable stage of land degradation, but, when not maintained by frequent fires and human disturbances, regenerate spontaneously and rapidly to secondary forest. The introduction of native shrubs and trees will speed up this process. Recovery for agriculture has not been studied but should not pose major problems under management system without fire. *Pteridium aquilinum* may induce stagnation in the regeneration of *Imperata* grasslands.

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