EFFECTS OF SHORT ROTATION NATURAL FALLOW ON DIVERSITY OF PLANT SPECIES AND POPULATION OF SOIL MICROBES IN APONMU, ONDO STATE, NIGERIA

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OKE DO. 2012. Effects of short rotation natural fallow on diversity of plant species and population of soil microbes in Aponmu, Ondo State, Nigeria. Bush fallowing is a common farming system in the humid zone of West and Central Africa. However, population pressures have resulted in shortened fallow periods with consequent effects on soil nutrients and biodiversity. To assess the effect of the shortened fallow period on plant species diversity, data were collected in a primary forest (forest reserve) and an adjoining 5-year-old bush fallow in Aponmu, Ondo State, Nigeria. Four plots of 25 × 25 m each were sampled from the forest reserve and one each from four abandoned fallow lands around the forest reserve. All trees with diameter at breast height greater than or equal to 5 cm were identified. A total of 0.25 ha of bush fallow and 0.25 ha of primary forest were surveyed. Ground vegetation was assessed from a subsample of 5 × 5 m in each of the sampled area. In the 0.25 ha of bush fallow surveyed, 64 individual trees were encountered (256 trees ha^{-1}) representing 34.2% of the tree density found in 0.25 ha of primary forest, which contained 187 individual trees (748 trees ha^{-1}). A higher value of Shannon's index (2.95) for the primary forest is an indication that it contains more variety of tree species per unit area than the bush fallow (2.37). There were slight differences in bacterial and fungal populations from the two ecosystems. This study indicated a lower number and variety of tree species under short rotation fallow. This may imply gradual loss of many of the benefits associated with trees.

Keywords: Tropical forest, Shannon's index, soil fungi, bacteria

OKE DO. 2012. Kesan rang semula jadi kala pendek terhadap kepelbagaian spesies tumbuhan dan populasi mikrob tanah di Aponmu, Ondo State, Nigeria. Rang belukar merupakan sistem perladangan yang biasa terdapat di zon lembap Afrika Barat dan Afrika Tengah. Namun, tambahan pesat jumlah penduduk menyebabkan kala rang menjadi lebih pendek dan ini mempengaruhi nutrien tanah dan kepelbagaian biologi secara langsung. Satu kajian telah dijalankan untuk menilai kesan kala rang pendek terhadap kepelbagaian spesies tumbuhan. Kajian dijalankan di sebuah hutan primer (hutan simpan) di Aponmu, Ondo State, Nigeria dan rang belukar berusia lima tahun yang berhampiran. Empat plot berukuran 25 m × 25 m disampel daripada hutan simpan dan satu plot berukuran 25 m × 25 m masing-masing daripada empat rang belukar terbiar yang berhampiran. Semua pokok berdiameter aras dada lebih atau sama dengan 5 cm dikenal pasti. Rang belukar seluas 0.25 ha dan hutan primer seluas 0.25 ha ditinjau. Vegetasi tanah dinilai dalam subsampel berukuran 5 m × 5 m yang diperoleh daripada setiap kawasan yang disampel. Sebanyak 64 pokok (256 pokok ha^{-1}) dicerap di dalam 0.25 ha rang belukar yang ditinjau. Bilangan ini mewakili 34.2% daripada jumlah pokok yang terdapat di dalam 0.25 ha hutan primer (187 pokok, 748 pokok ha^{-1}). Nilai indeks Shannon yang lebih tinggi dalam hutan primer (2.95) menunjukkan yang hutan primer mengandungi lebih spesies pokok seunit luas berbanding rang belukar (2.37). Terdapat sedikit perbezaan dalam populasi bakteria dan kulat antara kedua-dua ekosistem. Kajian ini menunjukkan yang bilangan dan kepelbagaian spesies pokok lebih rendah dalam rang belukar kala pendek. Ini mungkin menandakan kehilangan secara beransur-ansur faedah yang dikaitkan dengan pokok.

INTRODUCTION

The rich tropical rainforests in many parts of the humid tropics are disappearing at an alarming rate. Tropical deforestation has been attributed to timber extraction and agricultural expansion (Benhin & Barbier 2004, Donald 2004). Nigeria has the world's highest rate of deforestation of primary forests (Butler 2005). NEST (1991) reported that about 30,000 ha of forest and natural vegetation were lost annually in Nigeria. The country is reported to have lost 55.7% of primary forest to logging, subsistence agriculture, collection of fuelwood and other agents between 2000 and 2005 (FAO 2006).

Deforestation and the consequent loss of biodiversity have been of great concern to scientists and ecosystem managers all over the world. It has exposed the forest ecosystem to edaphic, ecological and environmental changes, reducing the stabilising functions of the forest. This has resulted in soil degradation, destruction of habitats and climatic instability. Many widely employed agricultural and forestry practices are having significant adverse effects on local and regional soil conditions, water quality, biological diversity, climatic patterns, and long-term biological and agricultural productivity (NRC 1993).

The major cause of deforestation in Nigeria is land clearing for agriculture. Shifting cultivation (bush fallowing) is believed to have caused the degradation of a large area of forest. Bush fallowing refers to a traditional practice where the farmer, after cultivating a piece of land for some years and the yield has begun to decline, abandons the land in order to allow it a resting period during which the fertility is expected to be restored. It is a common agricultural practice among smallholder Nigerian farmers. The normal sequence of fallow development is defined by soil and climatic factors, local plant species, agricultural technology in use and duration of the fallow. The general fallow regeneration pattern in the humid regions of West Africa has herbaceous grasses and broadleaved species as dominant plants during the first two to three years, during which they are interspersed with seedlings, root shoots or coppice regrowth of trees and tall shrubs. Therefore, for a natural fallow to sufficiently restore the fertility of an exhausted soil, a period of about 10 to 20 years is required.

In many parts of Ondo State, the reserved natural forests are being converted into agricultural lands under the shifting cultivation practice. Increasing demographic pressure has led to increased resource use and subsequent shortening of fallow durations. One of the resulting environmental consequences is the invasion of these landuse systems by *Chromolaena odorata* and other pioneer species. Apart from the negative impact of this on biodiversity, the deep rooting system needed for efficient nutrient recycling is usually lacking. Shortened fallows may affect the occurrence of many tree species which growth is normally at the later stages of plant succession sequence.

Plant species diversity also has indirect influence on the functionality of soil biota both on and beneath the forest floor (ground), especially soil microbes (Carney 2003). Soil microbes perform myriads of critical functions within the soil which include decomposition of organic matter and transformation of nutrients from one form to another. Soil microbes are the dominant force behind the nitrogen cycle in soil and their activities may determine the amount of nitrogen available for plant uptake (Knops et al. 2002).

This study was aimed at quantifying the impact of the shortened fallow periods on plant species diversity and population of soil microorganisms in Aponmu, Ondo State, Nigeria.

MATERIALS AND METHODS

Study site

The study was carried out in Akure Forest Reserve, Aponmu which lies on longitude 5° 3' N and latitude 3° 51' E in the rainforest vegetation zone of south-western Nigeria. The reserve covered a total land area of 69.92 km^2, of which 11.73% (8.2 km^2) was reported to have been encroached upon by farmers who took over the land to plant cocoa and other food crops (Adetula 2002). The topography of the reserve is relatively flat with some undulations. The soil is sandy loam overlying laterite gravel by the decomposition of underlying schist and quartz (Akinyemi et al. 2002).

Experimental design

Four sample plots of 25 × 25 m were demarcated along transect lines cut through the forest reserve. The first plot was located 10 m away from the main road and subsequent plots at a minimum distance of 75 m apart along the transect. Enumeration of plant species was done within each of the demarcated sample plot. Four abandoned fallow lands (five years of natural fallow) were selected from the encroached area very close to the forest reserve. One 25 × 25 m plot was demarcated within the centre of each fallow land and data were collected from each plot.

With the assistance of an experienced taxonomist, all trees species (diameter at breast height (dbh) > 5 cm) encountered in each of the demarcated sample plot were identified and their numbers recorded. For unknown tree species, leaves, slash and bark were collected and taken to the Forestry Research Institute of Nigeria, Ibadan for identification. The total number of each tree species encountered in the four sample plots (0.25 ha) for each ecosystem was calculated (frequency) and the figure was used in estimating the number of trees per hectare (tree density).

For assessment of undergrowth, 5 × 5 m subplots were sampled within each of the 25 × 25 m plots mentioned above. All plants located within these plots with dbh < 5 m were identified. Four ecological groups (regeneration phases) were used to categorise undergrowth following the classification by Budowski (1965) with modifications. Pioneer (very fast growth rate, low wood density, light demanding, gap coloniser, seed bank, short life span, ability to colonise disturbed sites), early secondary (fast growth rate, low wood density, light demanding, seedling bank, medium life span), late secondary (slow growth rate, high wood density, shade tolerant, gap opportunist, seedling bank) and climax (slow growth rate, high wood density, shade tolerant, seedling bank, large seed and long life span).

Soil cores (0–15 and 15–30 cm depth) were collected using a 3.5 cm diameter auger from five points within each of the demarcated plot. The auger points were located by randomly selecting five of the 12 points of intersection of grid lines drawn 5 m apart on each plot. Soil samples from the same soil depth on the same plot were bulked and a composite taken to the laboratory for analysis.

Plate dilution method was used for determining microbial population (bacterial and fungi) in the soil. Ten grams of soil were shaken with 90 ml of distilled water. From this suspension, the serial solution was prepared. An amout of 0.5 ml of the serially diluted solution was plated on agar by the pour plate technique (National Standard Methods 2004). Two main types of agar were used. Potato dextrose agar (PDA) was used for culturing fungi while nutrient agar (NA), bacteria. The plates were allowed to gel and fungi count was obtained from the mixed culture after seven days of incubation while bacteria count, after 24 hours. The colonies were counted using a Gallenkamp colony counter and expressed as colony forming units (cfu).

Statistical analysis

Values of microbial population were transformed into log (x + 1) where x = cfu g^{-1} of dried soil and compared using Student's t-test. Shannon-Wiener's diversity indices were computed for each plot in natural forest and bush fallow. The diversity index provides important information about variety and commonness of species in a community. Values of diversity index and tree density of the two types of plant communities were compared using Student's t-test.

RESULTS

Effect of short rotation fallow on plant diversity

In the 0.25 ha of natural fallow surveyed, 64 individuals belonging to 23 species and 12 families were identified (Table 1). The richest family was Sterculiaceae which had seven species. Euphorbiaceae had three species while Moraceae and Caesalpiniodeae had two species each. The predominant species were *Ricinodendron heudelotii, Sterculia oblonga, Albizia lebbeck, Gmelina arborea, Cola gigantea* and *Ficus exasperata* which accounted for 53% of the total tree population.

In the 0.25 ha of primary forest surveyed, 187 individual trees belonging to 34 species in 16 families were encountered (Table 2). The richest families were Sterculiaceae (6 species) and Moraceae (6 species). The dominant tree species were *Celtis zenkeri, Mansonia altisima, Triplochyton scleroxylon, C. gigantea, S. oblonga* and *Drypetes paxii.* The estimated mean tree density for natural fallow was 256 trees ha^{-1} and species diversity (Shannon's index) was 2.37, while mean tree density of 748 trees ha^{-1} and Shannon's index of 2.95 were recorded for the primary forest (Table 3). Comparison of tree densities and diversity indices from the two types of plant communities showed that they were significantly different (Table 3).

With regard to the ground vegetation of the bush fallow, 29 species from 22 families were encountered (Table 4). There was a predominance of plant species of the pioneer and early secondary ecological groups (Figure 1). Twenty plant species were encountered in the ground vegetation of the primary forest (Table 5). They were distributed in nine families with the pioneer ecological group being absent (Figure 1).

Table 1 Diversity of trees in the 0.25 ha of natural fallow in Aponmu, Ondo State, Nigeria

Species	Family	Frequency	Density (trees ha^{-1})
Ricinodendron heudelotii	Euphorbiaceae	7	28
Sterculia oblonga	Sterculiaceae	6	24
Albizia lebbeck	Mimosoidea	6	24
Gmelina arborea	Verbanadeae	5	20
Cola gigantea	Sterculiaceae	5	20
Ficus exasperata	Moraceae	5	20
Sterculia rhinopetala	Sterculiaceae	4	16
Terminalia superba	Combretaceae	4	16
Triplochyton schleroxylon	Sterculiaceae	3	12
Brachystegia eurycoma	Caesalpiniodeae	3	12
Myrianthus arboreous	Moraceae	2	8
Drypetes sp.	Euphorbiaceae	2	8
Cordia millenii	Bignoniaceae	2	8
Celitis zenkeri	Ulmaceae	1	4
Pterygota marcrocarpa	Sterculiaceae	1	4
Theobroma cacao	Sterculiaceae	1	4
Hildergardia bacteria	Sterculiaceae	1	4
Lecaniodiscus cupaniodesnch	Sapindaceae	1	4
Blighia sapida	Sapindaceae	1	4
Zanthoxylum zanthoxyloides	Rutaceae	1	4
Alchornea cordifolia	Euphorbiaceae	1	4
Cassia siamea	Caesalpiniodeae	1	4
Anacardium occidentale	Anacardiaceae	1	4
	Total	64	256

Effect of short rotation fallow on microbial population and diversity

Populations of soil microbes were slightly lower under bush fallow (Table 6). The mean bacterial population of soil from fallow was 3.2×10^6 cfu/g while that of soil from reserved forest was 3.7×10^5 cfu/g. The mean fungi population was 1.5×10^4 cfu/g in the soil from fallow while that of primary forest was 2.5×10^4 cfu/g. Although there were slight differences in the population of microbes under the two types of ecosystems, statistical analysis showed that they were not significant. Diverse populations of bacteria and fungi were encountered under the two vegetation types (Table 7). The most commonly isolated bacteria in the forest were *Staphylococcus* spp., *Streptococcus* spp., *Bacillus* spp. and *Actinobacillus* spp., while *Staphylococcus* spp., *Haemophyllus* spp. and *Corynebacterium* spp. were common in soil from the fallow area.

DISCUSSION

The 5-year-old bush fallow which followed clearance and cultivation of natural forest land had fewer tree species per unit area than the primary forest. Tree density was significantly higher in the primary forest compared with the fallow. Clearing of vegetation for arable crops may have resulted in loss of tree species. It is evident from this study that fertility of the land was not fully restored within the 5-year period. The Shannon's diversity index indicated that tree species diversity in the primary forest was significantly higher than in the bush fallow.

Although more plant species were encountered in fallow undergrowth compared with primary

Table 2 Diversity of trees in the 0.25 ha of primary forest in Aponmu, Ondo State, Nigeria

Species	Family	Frequency	Density (trees ha^{-1})
Celtis zenkeri	Ulmaceae	20	80
Mansonia altisima	Sterculiaceae	19	76
Triplochyton scleroxylon	Sterculiaceae	17	36
Cola gigantea	Sterculiaceae	14	56
Sterculia oblonga	Sterculiaceae	13	52
Drypetes paxii	Euphorbiaceae	10	40
Sterculia rhinopetala	Sterculiaceae	9	36
Cleistopholis patens	Annonaceae	8	32
Chrysophyllum albidum	Sapotaceae	7	28
Trichilia prieuriana	Meliaceae	6	24
Cordia millenii	Bignoniaceae	6	24
Pterygota macrocarpa	Sterculiaceae	5	20
Khaya ivorensis	Meliaceae	5	20
Ricinodendron heudelotii	Euphorbiaceae	5	20
Terminalia ivorensis	Combretaceae	5	20
Albizia zygia	Mimosoidea	4	16
Erythrophlem ivorensis	Mimosoideae	4	16
Lovoa trichiliodies	Meliaceae	4	16
Diospyrous mesopiliformis	Ebanaceae	4	16
Funtumia elastica	Apocynaceae	4	16
Zanthoxylum zanthoxylodies	Rutaceae	3	12
Bosqueia angolensis	Moraceae	3	12
Albizia lebbeck	Mimosoideae	3	12
Bligha sapida	Sapindaceae	2	8
Nauclea diderrichii	Rubiaceae	2	8
Antiaris africana	Moraceae	2	8
Ficus exasperata	Moraceae	2	8
Berlina confuse	Caesalpiniodeae	2	8
Alstonia boonei	Apocynaceae	2	8
Ficus mucuso	Moreceae	1	4
Myrianthus arboreus	Moraceae	1	4
Morus mesozygia	Moraceae	1	4
Terminalia superba	Combertaceae	1	4
Brachystegia eurycoma	Caesalpiniodeae	1	4
	Total	187	748

Table 3 Mean tree densities and Shannon's indices of short rotation bush fallow and primary forest in Aponmu, Ondo State, Nigeria

Parameter	Bush fallow		Natural forest	
	Mean	SD	Mean	SD
Tree density (trees ha^{-1})	256 b	22.63	748 a	40.00
Shannon's index	2.37 b	0.151	2.95 a	0.036

Means on the same row having different letters are significantly different ($p < 0.05$); SD = standard deviation

Table 4 Diversity and ecological groups of ground vegetation species in the 5-year-old natural fallow in Aponmu, Ondo State, Nigeria

Species	Family	Ecological group
Cola gigantea	Sterculiaceae	Late secondary
Sterculia rhinopetala	Sterculiaceae	Late secondary
Aerva lanata	Amaranthaceae	Pioneer
Chromoleana odorata	Compositae	Pioneer
Newbouldia laevis	Bignonaceae	Early secondary
Blighia sapida	Sapindaceae	Late secondary
Cytibula porstate	Amaranthaceae	Pioneer
Combretum nigricans	Combertaceae	Early secondary
Diospyrous mespiliformis	Ebanaceae	Climax
Drypetes paxii	Euphorbiaceae	Late secondary
Senna hirsute	Caesalpiniodeae	Pioneer
Trichillia prieuriana	Meliaceae	Late secondary
Mallotus oppositifolius	Euphorbiaceae	Early secondary
Myrianthus arboreous	Moraceae	Early secondary
Lonchorcarpus sericeus	Papilionidea	Late secondary
Celtis zenkeri	Ulmaceae	Climax
Ficus mucuso	Moraceae	Climax
Cassia siamea	Caesalpiniodeae	Early secondary
Funtumia elastica	Apocynaceae	Late secondary
Spigelia marilandica	Loganiaceae	Pioneer
Lecaniodiscus cupanioides	Sapindaceae	Early secondary
Brachystegia eurycoma	Caesalpiniodeae	Climax
Leucenea leucocephala	Mimosoidea	Pioneer
Mansonia altisima	Sterculiaceae	Climax
Ceiba pentandra	Bombacaceae	Late secondary
Sida acuta	Malvaceae	Pioneer
Commelia bagalensis	Commelinaceae	Pioneer
Draceana manni	Agavaceae	Early secondary
Panicum maximum	Granimae	Pioneer

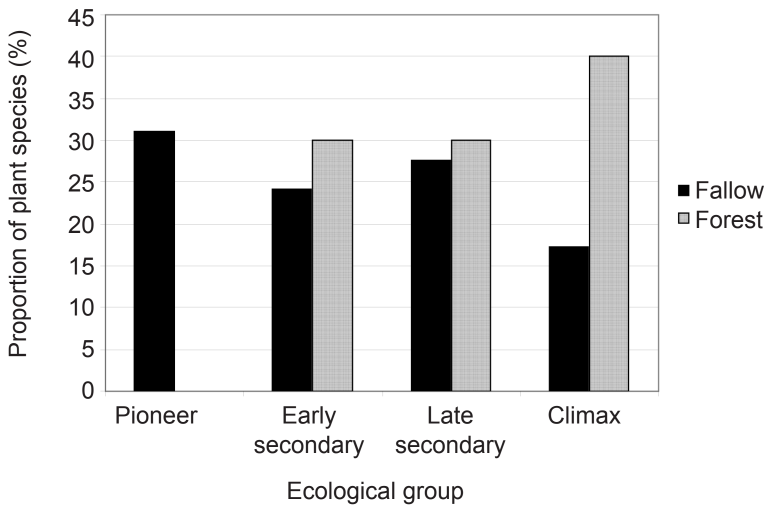

Figure 1 Proportion of ground vegetation species of primary forest and bush fallow in the various ecological groups

Table 5 Diversity and ecological groups of ground vegetation species in the primary forest in Aponmu, Ondo State, Nigeria

Species	Family	Ecological group
Funtunia elastica	Apocynaceae	Late secondary
Albizia zygia	Mimosodeae	Early secondary
Triplochyton scleroxylon	Sterculiacea	Climax
Sterculia tragacantha	Sterculiacea	Early secondary
Celtis zenkeri	Ulmaceae	Climax
Cordia millenii	Sterculiacea	Climax
Ricinodendron heudelotii	Euphorbiaceae	Early secondary
Khaya ivorensis	Meliaceae	Climax
Ficus mucuso	Moraceae	Climax
Cola gigantea	Sterculiacea	Late secondary
Alstonia boonei	Apocynaceae	Early secondary
Terminalia ivorensis	Combretaceae	Climax
Myrianthus arboreus	Moraceae	Early secondary
Drypetes paxii	Euphorbiaceae	Late secondary
Brachystegia eurycoma	Caesalpinodeae	Climax
Trichillia prieuriana	Meliaceae	Late secondary
Ficus exsaperata	Moraceae	Early secondary
Bosqueia angolensis	Moraceae	Late secondary
Antiaris africana	Moraceae	Climax
Morus mesozygia	Moraceae	Late secondary

Table 6 Bacteria and fungi count in cultured soil samples from primary forest and short rotation bush fallow in Aponmu, Ondo State, Nigeria

Microorganism	Natural forest		Bush fallow	
	x (cfu/g)	log x + 1	x (cfu/g)	log x + 1
Bacteria	3.7×10^5	5.67 ± 0.18	3.2×10^6	6.50 ± 0.10
Fungi	2.5×10^4	4.39 ± 0.89	1.5×10^4	4.17 ± 0.10

x = Bacteria or fungi count

forest, these were mainly herbaceous plant species of pioneer ecological group which did not contribute much to soil nutrient rejuvenation. This study revealed a reduction of 66% in tree density in the bush fallow compared with the forest. The short period of fallow may have truncated natural succession and affected the maintenance of tree diversity. Slaats et al. (1992) and de Rouw (1995) observed poor secondary forest regeneration in frequently cropped plots and this was attributed to a succession of short fallow periods that eliminated the seed and seedling bank of forest plants, thus, providing opportunities for annual weeds to produce several crops of persistent seeds. The frequency of disturbance witnessed in forest ecosystem naturally limits the long-term persistence of plant population in the system, thus, reducing the survival of shade-loving plants and this induces their extinction (Charles & Thomas 1995).

Difference in microbial population is a reflection of many factors such as nutrient and oxygen levels, temperature and availability of minerals (Haris 1962). The differences in both bacterial and fungal populations between the primary forest soil and fallow soil could then be attributed to possible change in nutrient and oxygen supply to the soils. Loss of hosts caused

Table 7 Species of bacteria and fungi isolated from cultured soil samples from primary forest and short rotation fallow in Aponmu, Ondo State, Nigeria

Microorganism	Natural forest	Natural fallow
Fungi	*Trichoderma* spp	*Aspergilus niger*
	Aspergilus niger	*Trichoderma* spp.
	Chlamidomyces palmorum	*Penicillium italicum*
	Rhizopus stolonifer	*Aspergilus rapens*
	Neurospora crassa	
	Aspergillus flavus	
Bacteria	*Staphylococcus epidermidis*	*Corynebactrium* spp.
	Staphylococcus aureus	*Staphylococcus aureus*
	Streptococcus lactis	*Haemophyllus* spp.
	Bacillus pumilus	*Micrococcus luteus*
	Actinobacillus equuli	*Peptococcus niger*
	Micrococcus luteus	*Lactobacillus lactis*
	Bacillus subtilis	*Sarcina flava*
	Actinobacllus lignieresii	
	Fusobaciterium symbiosum	
	Flavobacterium equatile	

by forest clearance and other human activities and disturbances that alter microclimates and exposure to sunlight are some of the factors that have been identified as threats to microbial diversity in tropical forests. Forest fragmentation may contribute to extinction of symbiotic microbes that are host specific and have poor dispersal abilities.

The essence of fallowing is to allow cultivated lands some time to regain the lost fertility and trees are known to play significant roles in nutrient recycling and soil rejuvenation. Species diversity loss is said to have significant effect on the association between soil microbes and roots of forest trees and in cycling of nutrients in forest (Kimmins 2004). It is clear from the results of this study that the short rotation fallows which contain fewer number of trees may not have the capacity to affect the soil as desired, hence, the decline in the output of the shifting cultivation system under short rotation fallow (Sanchez et al. 1983, Sanchez 2002, Hartemink et al. 2008). Alternative farming systems (such as the improved fallow system) which take adequate care of the short fallow occasioned by the population increase should be encouraged.

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