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IMMEDIATE EFFECT OF CLEARFELLING ON SOIL C, N AND P IN A HUMID TROPICAL FOREST IN ARUNACHAL PRADESH

K. Upadhyaya & A. Arunachalam*

Restoration Ecology Laboratory, Department of Forestry, North Eastern Regional Institute of Science and Technology, Nirjuli 791109, Arunachal Pradesh, India

Forests play a vital role in livelihood development in the humid tropics. The rich and diverse composition of forests, however, is exposed to different natural (landslides, floods) and human induced disturbances such as shifting cultivation and logging. In Arunachal Pradesh (northeastern India), about 19 km^2 of forest cover have been depleted from 1995 till 1997 (FSI 1997). The major causes of decline include shifting cultivation, illegal felling for timber and encroachment of land (Shukla 1992). This leads to the dwindling of valuable forest resources. It also affects the soil characteristics of forest. It is understood that soil nutrient status is determined by the immobilisation and mineralisation processes of the microbial component (Singh *et al.* 1989, Holmes & Zak 1999) by which they act as both 'sink' and 'source' of available nutrients to plants (Jenkinson & Powlson 1976). A long-term study was established on the structure and functioning of the forests in Karshingsa, Arunachal Pradesh and preliminary site evaluation was done. Unexpectedly, one of the study sites was clearfelled illegally. The vegetation and soil properties were immediately analysed after this felling. The aim of this study was to investigate the immediate changes in soil physico-chemical properties and microbial biomass after clearfelling of a 25-year-old broad-leaved humid tropical plantation forest in Arunachal Pradesh.

The study site is a plantation forest (2 ha) of 25 years old, located in Karshingsa at an altitude of 136 msl in the humid tropics of Arunachal Pradesh (26° 28' N latitude; 91° 30' E longitude), India. The dominant tree species were *Altingia excelsa, Phoebe goalparensis, Morus laevigata, Chukrasia tabularis, Lagerostroemia speciosa* and *Duabanga sonneratioides* with an understorey of *Piper* spp. and canes. The tree density was 140 ha^{-1}. The DBH of different trees ranged from 15 to 30 cm. The details of vegetation and microclimatic conditions of the site are presented in Table 1. The average annual rainfall was 1800 mm. Mean maximum and minimum air temperatures were 33° and 18 °C respectively. Soil was sandy loam.

Five permanent experimental plots of 10 × 10 m size were demarcated in the forest for sampling. The plots were 25 m apart from each other. From each plot, five soil cores (6.5 cm diameter) to a depth of 10 cm were collected. They were pooled and sieved through 2 mm mesh screen, then divided into three parts. One part of the soil was immediately analysed for pH (1:2.5 w/v H_2O), soil moisture content (SMC), ammonium-N (KCl extract; indophenol blue method), nitrate-N (deionised H_2O extract; phenol disulphonic acid method) and available-P ($NaHCO_3$ extract; molybdenum blue method). The second part was used for determination of microbial biomass-carbon (MBC), -nitrogen (MBN) and -phosphorus (MBP) using chloroform-fumigation extraction procedures (Anderson & Ingram 1993). The correction factor used for microbial C, N and P were MBC = MBC/0.45, MBN = MBN/0.54 and MBP = MBP/0.40 (Maithani *et al.* 1996). The third part of the soil was air dried and analysed for texture, bulk density, water holding capacity (WHC), organic-C (SOC) and total Kjeldhal nitrogen (TKN) using standard procedures (Anderson & Ingram 1993).

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**Author for correspondence. E-mail: arunachalam_in@yahoo.com*

Table 1 Vegetation and microclimate before and after felling in a humid tropical forest

Parameter	Before felling	After felling
Vegetation		
Tree density (ha^{-1})	140	–
Tree DBH (cm)	15–30 cm	–
Understorey vegetation (plants ha^{-1})	21391	20591
Average litter thickness (cm)	6.0	13.2
Litter biomass (kg ha^{-1})	987	2173
Microclimate		
Air temperature (°C)	28	33
Relative humidity (%)	62	54
Light intensity (lux)	2579	3149
Soil temperature (°C)	26	29
Soil moisture (%)	36.5	28.3

Soil samples were collected from the five experimental plots after clearfelling and were analysed for the above mentioned properties and microbial biomass. The percentage contribution of microbial C, N and P to SOC, TKN and available P was calculated and this information was used to evaluate the effect of clearfelling on the soil nutrient dynamics. Tukey's test was used to compare the mean values before and after clearfelling at a probability level of $p < 0.05$ (Zar 1974).

The reduced soil moisture content observed after clearfelling was attributed to the increased temperature and more evaporation caused by exposure to direct insolation. Soil turned highly acidic (pH 4.9) after felling and SOC, TKN and available-N (ammonium and nitrate) decreased significantly after felling (Table 2). In this regard, Holmes and Zak (1999) observed significant loss of N through nitrate leaching in hardwoods following clearfelling. On the contrary, Arunachalam *et al.* (1994) reported a significant increase in soil nutrients after a low intensity ground-fire in a subtropical climax forest of north-east India.

Tree felling affected MBC, MBN and MBP significantly. However, the influence of natural changes in the micro-environmental conditions on microbial biomass dynamics cannot be completely ruled out. Both MBC and MBN were higher in unfelled site. A reduction in soil moisture and direct insolation after felling might have affected microbial proliferation and resulted in low MBC and MBN. This is in accordance with the findings of Soderstrom (1979), Clarholm and Rosswall (1980), and Holmes and Zak (1999) although in different ecosystems where a positive correlation existed between fungal and bacterial biomass and soil moisture. In addition, the reduction in MBC and MBN may also be due to substrate exhaustion (decrease in SOM) in soil resulting in reduced microbial activity and less accumulation of these microbial nutrients in the soil after clearfelling. A similar reduction in microbial nutrients was observed in a tree-cut plot and in gaps of a *Pinus kesiya* forest of this region (Arunachalam *et al.* 1996). The dynamics of N in the mineral soil is intimately linked with that of C because most N exists as organic compounds and heterotrophic microbes utilise organic-C for energy (see Arunachalam *et al.* 1996). As a result, biomass-N also declined as microbial C decreased. Joergensen *et al.* (1995) also suggested that forest soils with comparatively low C and N availability may provide a microbial C:N ratio which is well below the optimum values of 5–8. However, in this study, the undisturbed forest soils with high SOC and mineral-N concentration recorded a very lowmicrobial C:N ratio of 3.0. This could be attributed to the soil specific differences in

Table 2 Soil properties before and after clearfelling in a humid tropical forest

Parameter	Before felling	After felling
Physical properties		
Textural class	Loamy sand	Loamy sand
WHC (%)	72 35^{a}	69 32^{a}
Bulk density (g cm^{-3})	1 28^{a}	1 09^{a}
SMC (%)	36 52^{a}	28 25^{b}
Chemical properties		
pH (1 2 5 w/v H_2O)	5 48^{a}	4 94^{b}
SOC (%)	2 78^{a}	2 61^{b}
SOM (%)	4 79^{a}	4 50^{a}
TKN (%)	0 55^{a}	0 25^{b}
C N	5 05^{a}	10 44^{b}
Ammonium-N (mg g^{-1})	0 07^{a}	0 02^{b}
Nitrate-N (mg g^{-1})	0 23^{a}	0 18^{b}
Available-P (mg g^{-1})	27 50^{a}	27 56^{a}
Microbial biomass		
MBC (mg g^{-1})	1644 44^{a}	1386 34^{b}
	(6 28)^{a}	(7 79)^{b}
MBN(mg g^{-1})	547 22^{a}	226 52^{b}
	(9 93)^{a}	(9 24)^{a}
MBP(mg g^{-1})	12 50^{a}	19 25^{b}
	(45 45)^{a}	(69 85)^{b}
MBC MBN	3 01^{a}	6 12^{b}
MBC MBP	131 56^{a}	72 02^{b}
MBN MBP	43 78^{a}	11 77^{b}

Values in parentheses are percentage contribution of microbial nutrients to respective soil nutrient pool
Values having similar letter do not differ significantly at the 0 05 probability level

growth form and survival strategy of the constituent micro-organisms that need further study According to Bremner and van Kessel (1992), the microbial biomass of the undisturbed forest was dormant because of a very small microbial C N ratio

Unlike microbial C and N, a reverse effect of felling was observed for microbial P as evidenced by almost 1 5 times increase in MBP after felling (Table 2) Nevertheless, soil available-P did not show any fluctuation in its concentration due to cutting This is understandable as P is a highly immobile element as compared with N (Arunachalam *et al* 1996) The proportion of microbial immobilisation of phosphorus (69 9%) was greater after felling which may imply that the role of microbial biomass in P conservation in disturbed ecosystems is significant Similarly, contribution of microbial C to SOC was also recorded higher after felling (7 8%) However, the percentage contribution of microbial N to soil total-N was comparatively greater (9 9%) before felling

This study indicates that (a) clearfelling affects the nutrient status of the soil and (b) in undisturbed forest soil, the role of microbial biomass to total soil N content is high, while in clearfelled system, its contribution is high to soil P and organic-C On comparison of this study with that of a ground-fire and gap/tree cutting induced changes in soil properties in a climax subtropical forest and a *Pinus kesiya* forest of this region, it could be stated that the type and intensity of disturbance is again crucial in determining the rate of soil nutrient flux

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