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SEASONAL EFFECTS ON THE SOIL ARTHROPOD COMMUNITY OF A DECIDUOUS TROPICAL FOREST

*Saowapa Sonthichai**

ABSTRACT

Seasonal change in Doi Suthep-Pui National Park at an altitude of 1130 m had various effects on the forest types, especially deciduous forest. In the dry season, the forest floor was covered with exessive leaf litter, and the soil lacked moisture. Man-induced fire was common. This affected the physical and chemical nature of the forest soil and its arthropod communities. Fire increased soil pH and reduced soil moisture retention and possibly the organic matter decomposition rate for several months. The number of arthropod families and number of individual arthropods were significantly reduced in the burnt area. Multivariate analysis, using Canonical Correspondence Analysis, showed a strong seasonal pattern in community structure, but patterns related to burning were less clear. TWINSPAN showed the classification of similar sample groups.

INTRODUCTION

Thailand has a tropical monsoon climate, showing distinct wet and dry seasons. The rainy season is from June to September, the dry season is from October to May and the weather is cold and hot, respectively. In the dry season, forest fires are frequent, especially in northern Thailand. Fire has a major impact on the productivity and biodiversity of deciduous tropical forest. Regular controlled burns have been advocated as a management technique to reduce the build up of litter and other fire fuels and to keep fire temperatures low enough, so as not to kill the adult trees (STOTT, 1988; KANJANAVANIT, 1992). However, the effects of fire or season change on other ecosystem components, especially soil, have not been adequately assessed. The soil contains a remarkably diverse community of arthropods which attains maximum complexity and abundance in undisturbed habitats (RAW, 1967). Fire not only destroys soil organic matter directly, but also disturbs the soil arthropod community, reducing its ability to mix dead organic matter into the mineral soil and cycle nutrients.

In this paper, I report on a study of the effects of seasonal change and fire on soil arthropod communities in a deciduous forest.

MATERIALS AND METHODS

The study was carried out in deciduous dipterocarp forest in Doi Suthep–Pui National Park, Chiang Mai, Northern Thailand. Immediately after a fire, ten samples of soil were collected randomly in a burnt area (BA) and another ten in an adjacent non-burnt area

*Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

(NBA). Twenty samples were similarly collected every month for a year. Soil was taken with a spade using 30 cm^2 quadrats, 10 cm in depth. The soil samples were extracted by Tullgren funnels and analysed for pH, moisture, organic matter, N, P, K, soil texture, field capacity and soil type, using standard techniques at the Faculty of Agriculture, Chiang Mai University.

To estimate decomposition rate, 24 nylon mesh bags (20 x 15 cm, with 2 mm mesh size) containing dried leaves, were weighed before being placed in the BA and NBA at random. Every month for a year, two bags from these areas were oven-dried and reweighed. Dry matter loss was used as an indicator of the decomposition rate.

The data were analysed as follows:

1. Taxonomic accretion curves were constructed using the data from the 10 samples of any month, from both the BA and NBA. The purpose of this was to determine if the number of samples was adequate for the study of the arthropod community.

2. a) Kruskal-Wallis and Mann-Whitney tests (SPSS for PC) were carried out to test for significant differences in communities between the BA and NBA.

b) Multivariate Analysis of community structure was carried out using the computer program CANOCO (TER BRAAK, 1988). The method is useful for showing relationships between the samples, or species, in the data tested. Usually the output can be compared separately to environmental data, to be used as part of the main analysis. This analysis, produces ordinations of samples and species and allows the inclusion of environmental data in the analysis. A Monte Carlo permutation test was performed, in order to show whether the observed differences can be accounted for by pure chance only.

c) Classification of samples was carried out by using the multivariate analysis program, TWINSPAN (TWo-way INdicator SPecies ANalysis), which is a polythetic divisive method of classification (HILL, 1979a). The classification process starts with the whole set of samples and progressively subdivides them. At each division there are more than one "species" determined. Similar samples will be grouped together. One side of the division is a list of indicator taxa. Another is an ordered two-way table, which allows the taxa found in the different sample groups.

RESULTS

Soil Characteristics

Analysis of soil texture showed that both the BA and NBA were a sandy loam in April and changed into sandy clay loam in March 1993. Available mineral nutrients such as N, P and K were examined every 3 months (Table 1). The mineral nutrients in the BA were higher than in the NBA in the first month, but after that the situation was in general reversed.

Figure 1 shows that the pH of soil in both the BA and the NBA was slightly less than neutral, except immediately after burning when the soil in the BA was alkaline. The latter may have been due to the presence of ash after burning. Subsequent pH readings in the BA and the NBA were very similar.

Table 1. Nutrient content and texture of soil in the BA and NBA (- = missing data)

Month	Area	Nutrient			Texture			Field capacity (% by weight)	Soil type
		% N	P (ppm)	K (ppm)	% sand	% silt	% clay		
April 1992	BA	0.334	33.50	512.50	63.52	17.84	18.64	26.01	Sandy loam
	NBA	0.193	11.00	118.75	65.52	19.84	14.64	19.38	
August 1992	BA	0.183	17.00	150.00	54.96	25.28	19.76	21.31	Sandy loam
	NBA	0.268	20.00	480.00	58.96	24.28	16.76	23.31	
Dec. 1992	BA	0.216	17.00	215.00	-	-	-	21.73	Sandy loam
	NBA	0.223	14.50	315.00	-	-	-	24.15	
March 1993	BA	0.171	33.50	165.00	49.68	22.56	27.76	24.09	Sandy clay loam
	NBA	0.238	22.50	315.00	49.68	26.56	23.76	26.32	

Moisture is the most important factor affecting the distribution of soil arthropods, since it strongly affects the development of arthropods in one or more of their life stages (RAW, 1967). Soil moisture increased from June to September as the rainy season progressed, as shown in Figure 2. Soil moisture in the NBA was slightly higher than in the BA, except in September and October. This was probably because there was more leaf litter covering the ground in the NBA, which absorbed water and helped reduce the rate of evaporation.

The rates of leaf litter decomposition were similar in both BA and NBA. Cumulative decomposition is shown in Figure 3. The very high values for the BA in some months such as in June, September and November were due to very high populations of termites that devoured and destroyed the nylon bags, thus causing high loss of material. The rate of decomposition increased markedly in both areas, most probably due to the proliferation of soil organisms. Furthermore, the rate of decomposition is higher in NBA than BA. It seems that burning decreases the rate of decomposition but this experiment really needs to be repeated.

Figure 4 compares levels of % organic matter between the BA and NBA. Generally, organic matter in the NBA was higher than in the BA, except in April, when the high value may have been caused by ash from leaf litter. Moisture also affects soil organic matter: when moisture was high, the organic matter increased (Figures 2 and 4). Macroarthropods such as millipedes and isopods are important comminuters of detritus (WALLWORK, 1970), and moisture is necessary for their activities. Some microarthropods such as mites and springtails cannot ingest freshly fallen leaves, particularly if the leaves are dry, but prefer moist, partially decomposed litter (BARBOSA & WAGNER, 1989). The organic matter in the soil mostly came from leaf litter that had been broken down by bacteria and soil organisms.

Taxonomic Accretion Curves

Figure 5 shows taxonomic accretion curves produced from 10 sample taken at each of the BA and NBA in April. Eight samples include 91% of the total families found, for both the BA and NBA, while 9 samples include 96% and 96.1% for the NBA and BA respectively. The curves reach an upper steady state by the ninth sample.

Sample Diversity

The deciduous forest soils had a mor humus formation, where the organic matter forms a discrete layer on the soil surface. The dominant arthropod groups were dipteran larvae, elaterid larvae, Diplopoda, Collembola and Acari (RAW, 1967). In this study, seven classes of soil arthropods were found, Arachnida, Chilopoda, Crustacea, Diplopoda, Pauropoda, Symphyla and Insecta. The last was represented by the orders Collembola, Orthoptera, Isoptera, Neuroptera, Psocoptera, Protura, Hemiptera, Dermaptera, Trichoptera, Diptera, Coleoptera, Lepidoptera, Hymenoptera and Thysanoptera. Altogether 136 soil arthropod families, both larvae and adults, were identified (Protura, Pauropoda and Symphyla were classed as "families" due to difficulties in identification).

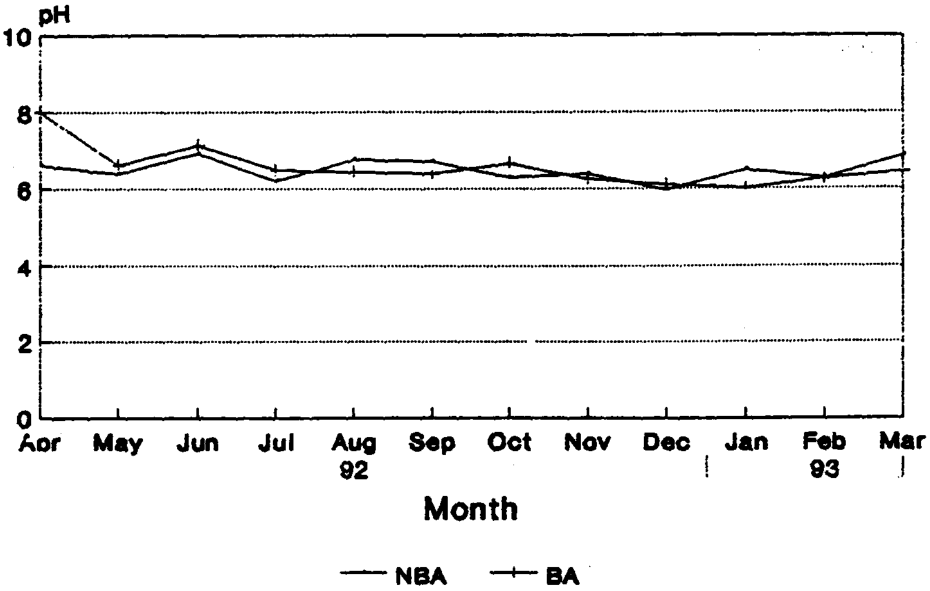

Figure 1. pH of soil in Burnt (BA) and Non-burnt area (NBA) over the year.

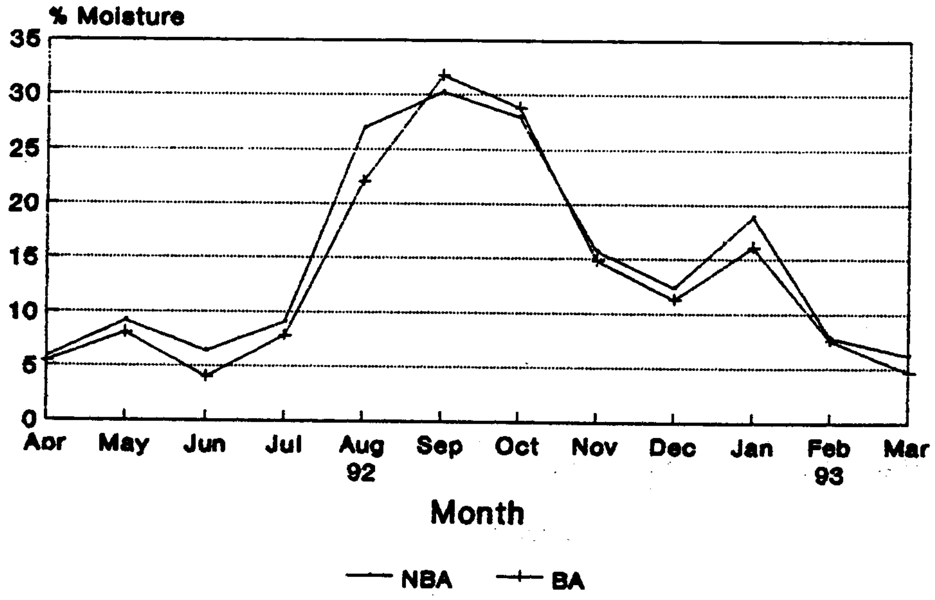

Figure 2. Soil moisture changes in Burnt (BA) and Non-burnt area (NBA) over the year.

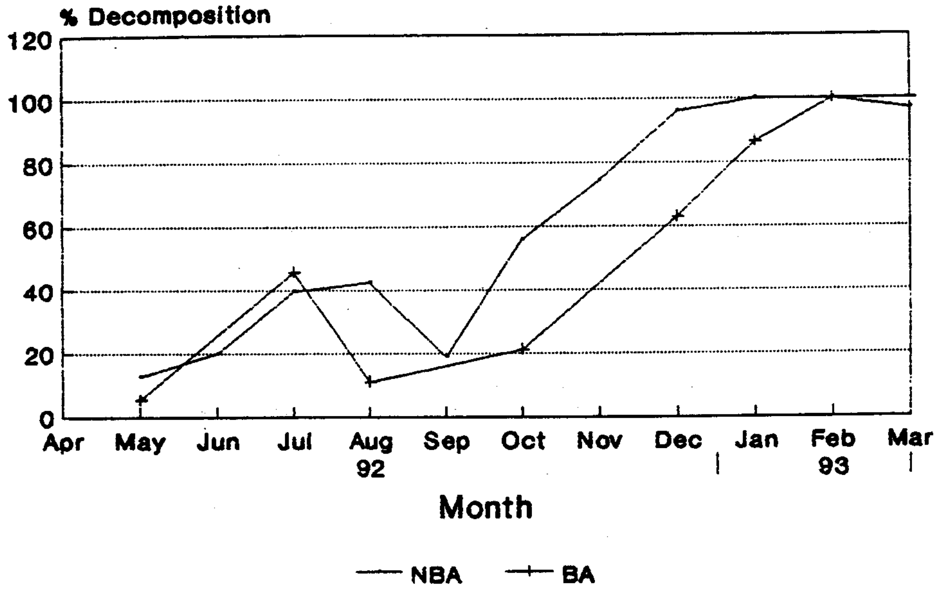

Figure 3. Decomposition of leaf litter in Burnt (BA) and Non-burnt area (NBA) over the year.

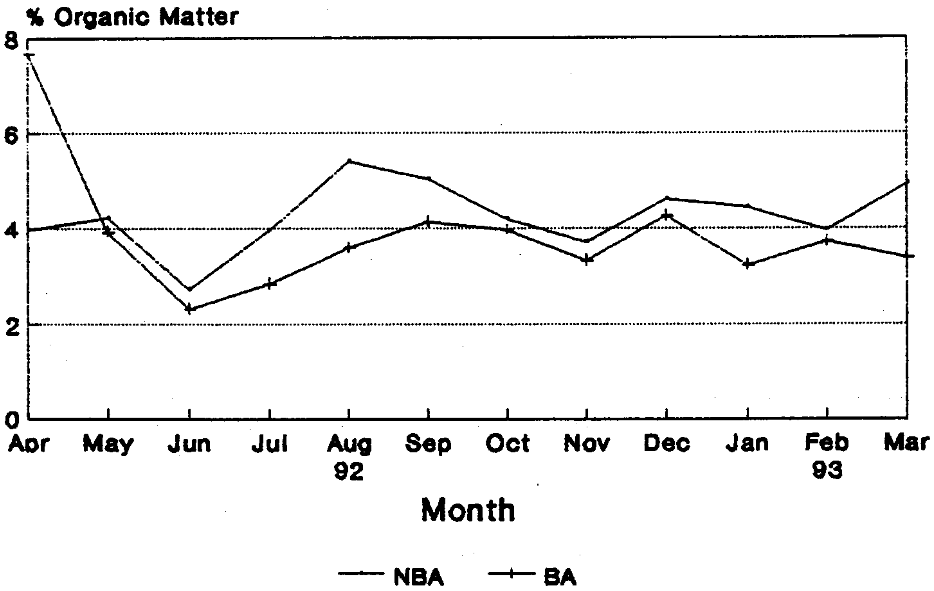

Figure 4. Organic matter changes in Burnt (BA) and Non-burnt area (NBA) Over the year.

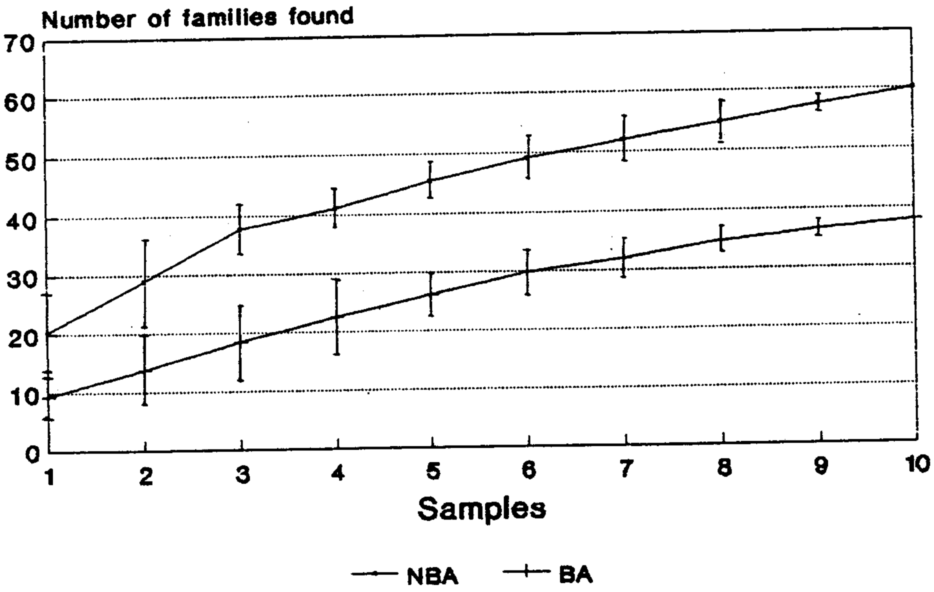

Figure 5. Family accretion curve (Vertical bars = Standard Deviations)

Figures 6 and 7 show the number of families and the number of individuals found in the BA and NBA in each month. A Kruskal-Wallis non-parametric ANOVA showed that NBA had significantly more families at the 0.01 significance level and had significantly more individuals than the BA ($p \leq 0.05$).

Figures 8–10 are the ordination diagrams produced by Canonical Correspondence Analysis, using the program CANOCO. The species scores, sample scores and centroids of the environmental variables (hot, wet and cold season) are ordinated on axes 1 and 2. The first axis separates the wet season samples from those of the cold and hot (dry) season. The second axis separates the cold and hot season samples. The families occurring near each of the sample groups occur mainly in the season from which those samples come. To investigate whether the observed differences could be accounted for by pure chance, a Monte Carlo permutation test was used, with the first eigenvalue as the test statistic. The 99 random data sets generated by random permutation of seasons all yielded a lower value. It was therefore concluded that there were significant differences in invertebrate communities among the seasons ($p \leq 0.01$).

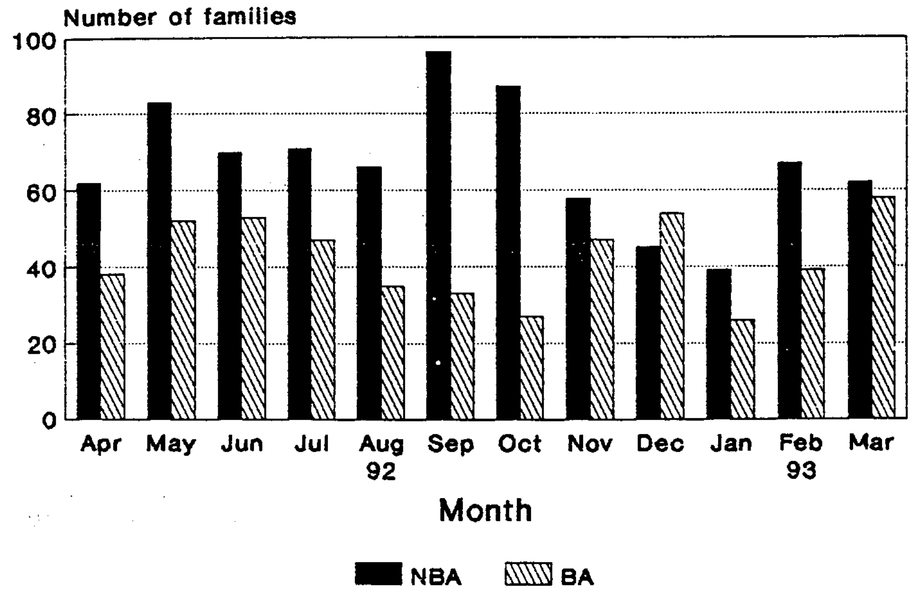

Figure 6. Number of families per overall sample in the BA and NBA. A Kruskal-Wallis non-parametric ANOVA showed that there was a significant difference in number of families between the BA and the NBA samples ($p \leq 0.01$).

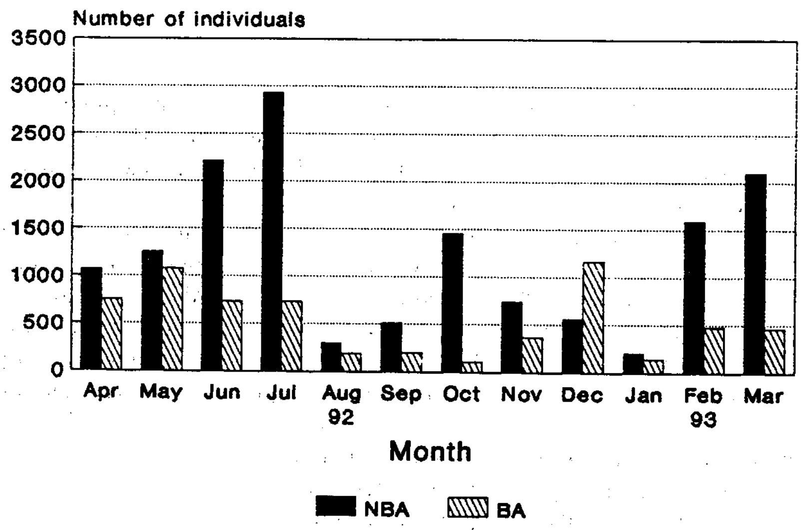

Figure 7. Number of individuals per overall sample in the BA and NBA. A Kruskal-Wallis non-parametric ANOVA showed that there was a significant difference in number of individuals between the BA and the NBA samples ($p \leq 0.05$).

To investigate whether effects due to burning would be revealed if the seasonal influence was removed from the data, a further analysis was carried out. The seasonal variables (hot, wet and cold season) were treated as covariables and the variables related to burning (burnt, non-burnt, pH, moisture, decomposition, organic matter) were treated as the variables of interest. The output ordinations revealed a slight pattern related to burnt or non-burnt status, but a restricted Monte Carlo permutation test of 99 permutations showed that this was only significant at the 10% level.

Figure 11 shows the results of a classification of all of the samples from both BA and NBA. It is notable that all of the wet season samples were grouped to the right. All of them indicated by the order Acari. The hot and cold season samples were not well separated in the classification. Both of these seasons are dry; therefore moisture has a more important influence on community than temperature. The analyse did not separate NBA from BA samples.

DISCUSSION

Soil nutrients are necessary for the growth of plants. Bacteria and soil animals are important in the breakdown of organic substances, particularly plant debris. Burning destroys organic matter and also arthropods in the upper few centimetres of the soil. In humid tropical areas, organic matter is often the only source of soil nutrients. Therefore, fires influence the physical and chemical characteristics of the upper soil. Common changes include increasing soil pH (Figure 1), reducing soil pore-size and aeration, for example by changing sandy loam into sandy clay loam. The ash produced by most plant materials and tends to raise the pH of acid soils that are poorly buffered. The increase in pH after fire favours bacterial population growth over fungal population growth so bacteria change plant debris into organic matter (Figure 4) (De Ronde et al., 1990). From Table 1 it can be seen that nitrate levels after the fire were high. After burning, bacteria were destroyed and consequently N_2–mineralization decreased. Thus nitrate levels decreased 3 months later. Nitrate levels in the NBA increased compared to the BA, where levels fluctuated. Nitrate levels may be linked to soil moisture levels, which were observed to vary widely (Figure 2), as these affect the growth of bacteria.

It is important to understand the effects of fire on soil arthropods, since these animals have a direct and major role in the decomposition of litter and nutrient (Moore et al., 1988). Fire significantly reduced the population density of arthropods in the soil and also reduced the number of families occurring in given volumes of soil. The reduction in family number is probably not just a result of inadequate sample size in the BA, as the taxonomic accretion curves for both the BA and NBA were in the steady state at the ninth sample. Multivariate analysis, however, which analyses overall community structure, rather than just numbers of individuals of families, showed that seasonal factors were having a much greater effect, with changes related to fire being much less prominent. It would therefore appear from the data that burning produces certain gross effects on the arthropod communities, including a reduction in the number of families and population density, but that the basic community structure in both the BA and NBA is still quite similar in fluctuating all year round. Seasonal factors have the dominant influence. Furthermore, the TWINSPAN analysis of

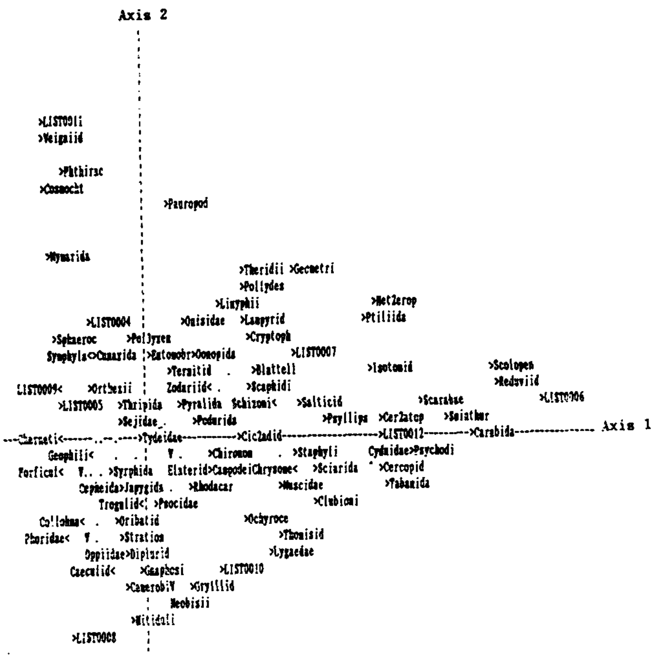

Figure 8. Ordination diagram based on canonical correspondence analysis of soil arthropods with respect to season.

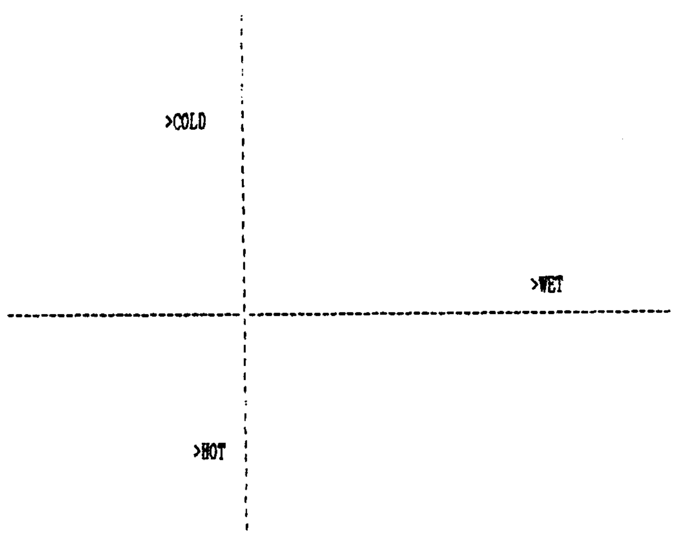

Figure 9. Centroids of environmental variables (Mean GT. 0) in ordination diagram.

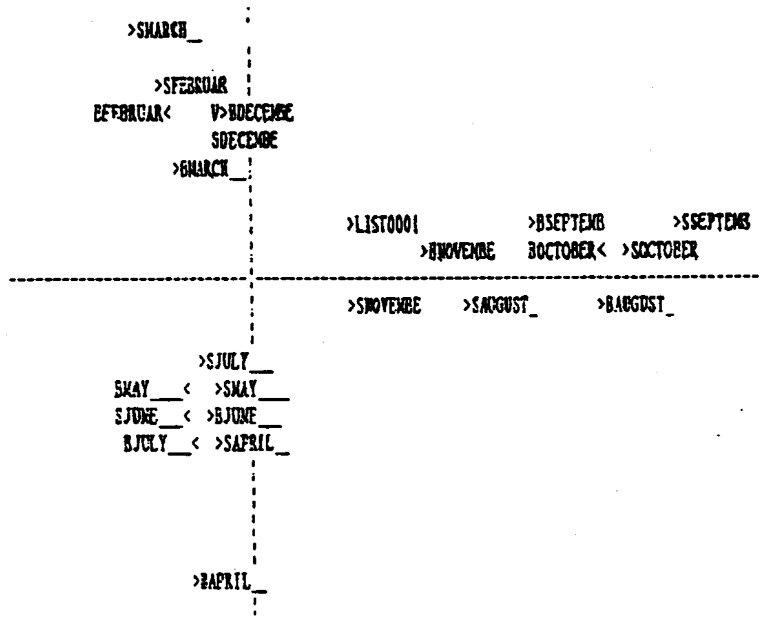

Figure 10. Sample scores showed that groups on axis 1 and 2 were in WET and COLD season respectively and the rest were in HOT season. (B = Burnt area; S = Non-burnt area)

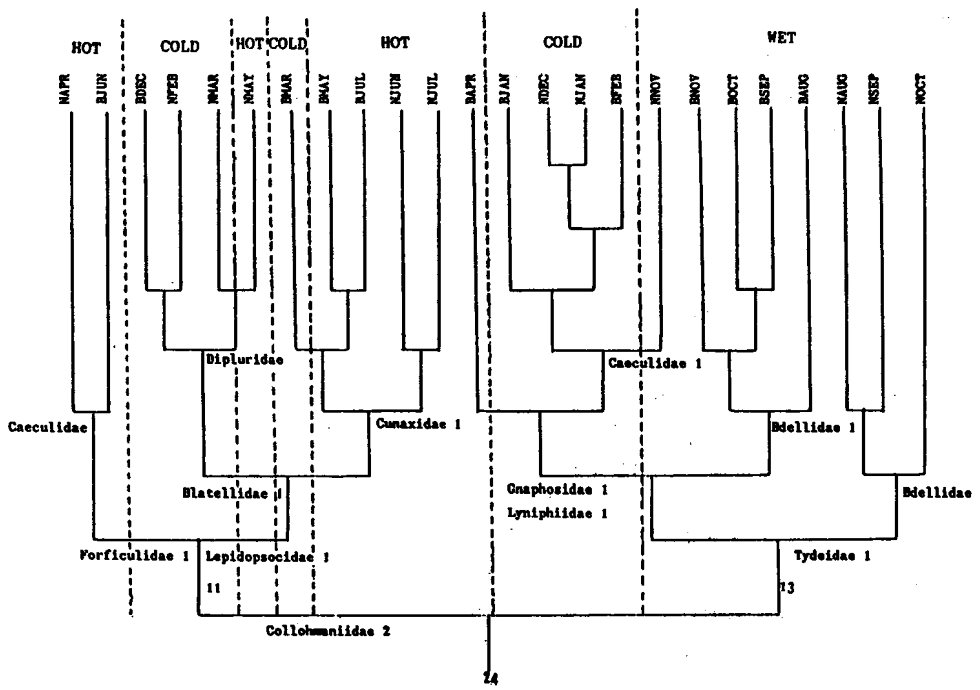

Figure 11. TWINSPAN classification of all samples (B = Burnt; N = Non-burnt).

the data also revealed a seasonal pattern. However, a reduction in arthropod population density after burning would be expected to have large effects on soil quality as processes such as nutrient cycling would be slowed down. Fortunately, the fires on Doi Suthep tend to be of relatively low temperature, as STOTT (1988) noted that 300°C is the upper limit. Higher temperatures would be expected to have even greater effects on arthropod communities.

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REFERENCES

BARBOSA, P. AND M.R. WAGNER. 1989. *Introduction to Forest and Shade Tree Insects.* Academic Press, Inc. New York. pp 639.

HILL, M.O. 1979a. *TWINSPAN–a FORTRAN Program for Arranging Multivariate Data in an Ordered Two–way Table by Classification of the Individuals and Attributes.* Ithaca, New York. Cornell University. pp 45.

KANJANAVANIT, S. 1992. Aspects of the temporal pattern of dry season fires in the dry dipterocarp forests of Thailand. Ph. D. Thesis. University of London.

MOORE, J.C., D.E. WALTER AND H.W. HUNT. 1988. Arthropod regulation of micro–and mesobiota in below–ground detrital food webs. *Ann. Rev. Entomol.* 23: 33–40.

RAW, F. 1967. Arthropoda (except Acari and collembola). Pages 323–362 in A. Burges (ed) *Soil Biology.* Academic Press, London.

RONDE, C. DE, J.G. GOLDAMMER, D.D. WADE AND R.V. SOARES. 1990. Prescribed fire in industrial pine plantations. Pages 216–272 in J.G. Goldammer (ed) *Fire in the Tropical Biota.* Springer-Verlag, Berlin.

STOTT, P. 1988. Savanna Forest and Seasonal Fire in South East Asia. Pages 196–200 in *Plants Today,* November–December, 1988.

TER BRAAK, AND J.F. CAJO. 1988. Groep Landbouwwiskunde. Agricultural Mathematics Group, Box 100, 6700 AC Wageningen, the Netherlands.

WALLWORK, J.A. 1970. *Ecology of Soil Animals.* McGraw-Hill, London, pp 283.