ECOLOGICAL STUDIES OF SOIL ARTHROPODS IN FOREST AND JHUM SYSTEMS OF LAITKOR, MEGHALAYA

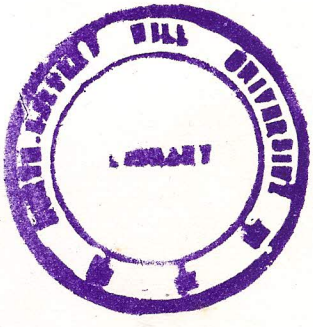
By

Vincent Thansanga Darlong, M. Sc.

DEPARTMENT OF ZOOLOGY
SCHOOL OF LIFE SCIENCES

SUBMITTED IN FULFILMENT OF THE REQUIREMENT
OF THE DEGREE OF

DOCTOR OF PHILOSOPHY



To

THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG-793001
INDIA

NOVEMBER, 1984

भारत सरकार
GOVERNMENT OF INDIA

तार का पता :
'जूलसर', शिलांग
Tel. address :
''Zoolsur, Shillong''
Phone-23638

पूर्वीय प्रादेशिक केन्द्र,
भारतीय प्राणी सर्वेक्षण,
रीसा कालोनी, शिलांग।
EASTERN REGIONAL STATION,
ZOOLOGICAL SURVEY OF INDIA,
RISA COLONY, SHILLONG-7930

No. F.

Dated

Dr. J.R.B. Alfred,
Deputy Director

I certify that the thesis entitled "Ecological Studies of Soil Arthropods in Forest and Jhum Systems of Laitkor, Meghalaya", submitted by Mr. Vincent Thansanga Darlong for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the Award of the Ph.D. Degree. This work has not been submitted for any Degree of any other University.

Dated : November 17th, 1984
Place : Shillong.

Signature of the Supervisor.

A C K N O W L E D G E M E N T

An investigation of this type would be beyond the capacity of a single individual and I have received valuable assistance from many people. It is a pleasure to acknowledge their contributions.

To Dr. J.R.B. Alfred, formerly Reader in Zoology, NEHU, and now Deputy Director, Eastern Regional Station, Zoological Survey of India, Shillong for supervision, constant encouragement and direction with experienced judgement and effort beyond the call of duty, I owe a great debt of gratitude.

I record my deep appreciation to Dr. J.P. Thapliyal, FNA, Professor and Head, Department of Zoology, NEHU, for the facilities extended to me and more so, for his kindness and understanding. I am most happy to acknowledge my debt to Prof. R. George Michael and Prof. M.K. Khare, former heads of the department, for their encouragement and advice. That the present work was initiated under their tenure is gratefully recalled and acknowledged.

Thanks are also due to Prof. R.R. Mishra, Dean of the School of Life Sciences, Dr. R.K. Rai, Head of Geography Department and Prof. R. Lalthantluanga, Head of Biochemistry Department for their kind permission to avail the facilities of duplicating machine, Microsystem 1120 and Moscal calculator, respectively.

Dr. S.K. Mitra, Superintending Zoologist, Zoological Survey of India, Calcutta had kindly identified the collembolan species. My former teacher at St. Anthony's College, Shillong, Prof. R.K. Bhattacharjee donated the type-specimens of *D. singularis* and *D. fraternus* for my ready reference. The acarine species were identified by Dr. A.K. Sanyal, Zoologist, ZSI, Calcutta. Dr. Haridashan, Dr. S. Jamir

and Dr. S. Myrthong helped me in the identification of the plant species. To all of them I feel immensely indebted.

The assistance received from colleagues and friends, particularly Prabhakaran, Amal, Pinku, Debu, Mipun, Hattar, Didi, Achintya, Dilip, Barnabas, Golden, Julian, Yogendra, Goel, Mrs. P. Chaurasia, Bijoyda (for the photography), Salil (for the line diagrams) and Bah Nah are formally and gratefully acknowledged. And to Catherine, I only say "Thank you very much" for I know best all that she deserves in the making of this thesis.

Finally, I owe much to the farmer, who had willingly sacrificed a portion of his farmland (jhum fallow) for two years, knowing only that it meant something for "science".

(Vincent Thansanga Darlong)

C O N T E N T S

.....

P L A T E S

.....

F I G U R E S

.....

TABLES

.....

1. INTRODUCTION AND REVIEW OF LITERATURE

1.1. General introduction

A forest ecosystem comprises one of the most complex of communities. Trees, shrubs, herbs and mosses are the easily perceptible botanical components of such a community. Moulds, bacteria, algae and other lower plants are less conspicuous. The animal components of this ecosystem are much less striking, particularly those that live in/on the soil. Nevertheless, all phyla of the animal kingdom, possessing a terrestrial mode of life, composing of species of great diversities and sizes, are represented in the forest ecosystem. It is near to impossible for studying the total animal kingdom in such a forest ecosystem. Hence, for the present investigation and with particular reference to the work it is intended to convey, we confined our study to the soil components of this vast ecosystem.

The pedological literature abounds in definitions of soil in terms of its state, of its function and of factors and processes of its formation. Soil is that land cover of solid, liquid and gaseous materials. It lies below the observable interphase between the atmosphere and forest floor or grass-sedge or cropped land floor, and above the geologic substratum that appears relatively unaltered (Hole, 1981). The soil is also usually inclusive of the litter of organic debris. It is actually a major multilayered stratum in a larger and even more complex biocenose (Ghilarov, 1968).

This soil teems with life, inhabited by a bizarre assortment of living creatures. Soil fauna or soil animals as they are known collectively, is a broad term, and may be defined as one that participates in the dynamics of a soil body (Hole,1981) or applicable to all groups of animals which spend their life wholly or partly, in soil and litter (Drift, 1951).

Of these, the phylum Arthropoda, which include more known species of animals than all other groups of living organisms together, also contain the greatest diversity of soil inhabiting species. Kuhnelt (1963) had observed that there was hardly an arthropodan group which was not found in the soil. However, this bulk of arthropodan fauna in the soil is represented by Acarina and Collembola (Kevan, 1965), and other less abundant groups like Symphyla, Pauropoda, Protura, Diplura, Hymenoptera, Chilopoda, Diplopoda, Coleoptera, Araneida, Isopoda, Psocoptera, Dermaptera, Orthoptera, Diptera, Pseudoscorpionida, etc. Nematodes, enchytraeids, earthworms, molluscs and protozoans also form a major portion of the soil biocenose. However, for the present work, soil fauna would mean the arthropod fauna in soil in general with Collembola and Acarina in particular.

With the above in mind, the present investigation was carried out on these soil fauna, not only in the forest soil but simultaneously in that of a man-induced system, viz. jhum, also. The main objectives of the present work were to identify the various soil arthropod groups, their densities, population fluctuations and their intricate relationships with various

edaphic and climatological factors for at least two annual cycles. Though this could be looked at from individual and population levels, while making comparisons between two such systems as forest soil and jhum soil, it would be necessary to have community relationships at least for the major faunal groups. Moreover, the idea was to arrive at similarity indices between two such systems using the community data. The latter would enable an understanding into the colonization and successional patterns of these faunal groups in a disturbed soil condition as compared with that of a supposedly stable forest ecosystem.

1.2. The growth of soil zoology

Soil fauna represent one of the most complex, difficult and rewarding areas of current biological exploration. Contact with this frontier has received inadequate attention from pedologists for a long time, despite early works by White (1789) Darwin (1840, 1881) and Muller (1879, 1884) on earthworms and other invertebrate soil fauna, evaluating their role in humus formation. In greater details, the general studies of soil fauna has, however, begun with Diem's (1903) pioneering investigation of certain Swiss alpine soils, and subsequently supplemented by the contributions of Cameron (1913), Bornebusch (1930), Joffe (1936), Frenzel (1936), Jacot (1940), Forsslund (1945), Kubiena (1948) and Gilyarov (1949), who had drawn the attention of pedologists to the important role of animals in the formation of soil.

It may, perhaps, be argued that soil zoology has been developing towards maturity as a discrete discipline for the last thirty or forty years. Landmarks in this maturation process include the appearance of Kuhnelt's (1950) Bodenbiologie, produced in an English edition in 1961, summarizing the greater part of what was known about soil animals, and Franz's (1950) Bodenzoologie, in which he emphasized the practical implications of the study of the soil fauna.

These works heralded rapid spawning of concurrent literature and international symposia, devoted exclusively to soil animals, culminating in the publications and compilations of Delamare-Debouttéville(1951), Hartmann(1951), Drift (1951), Lawrence (1953), Kevan (1955, 1962), Nosek (1957), Farb (1959), Murphy (1962), Doeksen and Drift (1963), Burges and Raw (1967), Graff and Satchell (1967) and Vanek (1975). These authors have drawn together a considerable amount of information on the general biology and ecology of soil animals, and have done much to stimulate interest in this field. Also symptomatic of this interest was the creation of international journals of soil biology and ecology, viz. Pedobiologia in 1961 and Revue D'Ecologie et de Biologie du Sol in 1964.

Thereafter, research on soil fauna has been pursued with vigour by increasing number of investigators, as evidenced by rapid accumulation of literature on soil fauna. Texts on animal ecology, which have long paid scant attention to soil animals, have also given increasing recognition to soil fauna, and

some of them (Tischler, 1955; Macfadyen, 1957, 1963a; Balogh, 1958) lay heavy emphasis upon it.

The rapid accumulation of literature on soil fauna during this period was also due to simultaneous availability of improved soil fauna sampling techniques, largely due to the works of Macfadyen (1953, 1955, 1961a) and Alexander and Jackson (1955), though most were improvements and modifications of Tullgren's(1917) apparatus. Further evidence of rapid expansion since 1950, of the discipline of soil zoology has been treated by Wallwork (1970, 1976), Franz (1975) and others.

With the inception of the International Biological Programme in 1964, which aims at "world study of biological productivity and human adaptability", soil ecology studies has been sponsored by the section on terrestrial productivity. The result of this programme was the birth of an IBP Handbook, entitled, "Methods of Study in Quantitative Soil Ecology : Population, Production and Energy Flow" (Phillipson, 1971), which describes methods for biological research in soil ecology. This was also indicative of the beginning of quantitative approach to soil faunal studies with special reference to productivity and energy flow, which is now major thrust-areas of many soil faunal investigations in different parts of the world.

The last (and the 8th in the series) International Colloquium on Soil Zoology was held in September 1982 at the Catholic University of Louvain, Belgium. The Colloquium proceedings appeared in a volume: "A New Trend in Soil Biology", (Lebrun et al., 1983).

1.3. Soil fauna studies in India

Systematic survey of literature on Indian soil fauna in general and soil arthropods in particular, is difficult as they are distributed in obscure journals. Scanty literature on the subject speaks of its poor attention received from Indian pedologists. Nevertheless, there is growing evidence of interest among Indian workers as indicated by the proceedings of the two national symposia "Soil Biology and Ecology in India" (Edwards and Veeresh, 1978) and "Progress in Soil Biology and Ecology in India" (Veeresh, 1981). These publications attempt to bridge the gap in the knowledge of soil biology and ecology in this country, which is, as yet insignificant when compared to her vast landscape variations and severe pressures on her fragile soils. Added to this venture is the creation of Indian Journal of Soil Biology and Ecology, the first issue of which appeared in September 1981. The recent appearance of a volume entitled, "Applied Soil Biology and Ecology" (Veeresh and Rajagopal, 1983) is indeed a landmark in the progress of the study of soil fauna in India. The State of Art Report : Zoology(1980) also gives comprehensive idea of the current status of soil zoology, particularly persons and institutions engaged in studies and reserach in the country and elsewhere.

The earliest taxonomic records of soil fauna from the Indian sub-continent dates back to Pocock (1892), reporting upon the ground-dwelling myriapods of the then Ceylon (Sri Lanka) and Southern India. Writing on the then British India, Bingham

(1903) reported on many of the ground-dwelling ants. While Imms (1912) and Carpenter (1917) described new collembolan genera and species of this sub-continent, contributions on acarine systematics and taxonomy were made by Pearce (1906), Ewing (1910), Jacot (1933) and Baker (1945).

Ecological investigation of soil arthropods in India was first undertaken by Trehan (1945), who reported on the density-fluctuations of microarthropods in seasons and effects of various factors on them as existed in a cotton field environ of Lyallpur (now in Pakistan). Shrikande and Pathak (1948) attempted to evaluate the roles of insects and earthworms in soil fertility. With these initial ecological works it was, however, appropriate that Dhillon (1964a,b) emphasized on the sampling tools, techniques and extraction apparatus for the ecological investigations of soil microarthropods as would have been suitable to Indian context.

Qualitative and quantitative studies of microarthropods occurring in association with different crop plots and uncultivated fields are known through the works of Mukharji and Singh (1967, 1970), Singh and Mukharji (1971, 1973), Singh and Pillai (1975, 1981), Prabhoo (1976), Gupta and Mukharji (1976a, b, 1978), Bhattacharya and Raychaudhuri (1979), Veeresh *et al.* (1981), Pai and Prabhoo (1981), Haq *et al.* (1981) and Rishi (1981). The contribution of Banerjee (1972) was the only exception deviating from general population studies to the role of microarthropods in humus formation. Reports on tropical decidu-

ous forest soil and litter microarthropods are limited in the works of Singh and Singh (1975) and Singh and Mahajan (1981). The soil and litter mesofauna of evergreen forests of the Himalayas in Kashmir is known through the works of Raina et al. (1981). Hazra (1982) made a preliminary report of the soil arthropods of Silent Valley.

To these general Indian workers, fragmentary knowledge of the soil fauna of North-East India is through the limited reports in papers by Reddy and Alfred (1977, 1978a,b) and Reddy (1980, 1981), Hattar and Alfred (1984) and Paul and Alfred (1984) concentrating on the arthropod populations of the pine forest floors at higher elevations of Meghalaya; Vatsauliya and Alfred (1980, 1981) and Vatsauliya (1981) reporting on the soil fauna of jhum fallows at lower elevations; Darlong (1979) and Darlong and Alfred (1982, 1984) showing the differences in the arthropod structure in the forests and jhum fallows of this region.

1.4. Literature on the fauna of forest soils

For the purpose of the present study, the following summary of the most important literature is confined to those investigations that concern the whole fauna or arthropod groups of the forest soils. The first to make a comprehensive investigation into the forest soil fauna was Diem (1903), on the Swiss alpine forests. Ramann (1911) described fauna of forest soils in Germany. He was perhaps one of the first to reveal the great importance of soil fauna in humus formation.

In Bavaria, an investigation into the composition of litter fauna in pine forests was made by Pillai (1922) and some years later Pfetten (1925) made a similar investigation for a spruce wood. They showed that great numbers of fauna occur in the forest litter layer and that a quantitative study can be performed in considerably smaller samples.

Grimmett (1926) studied the soil fauna of a beech forest in New Zealand. He examined his samples for the macrofauna and consequently, his recovery for the microfauna, such as mites and collembolans were appreciably low.

In Czechoslovakia, Soudek (1928) made a comprehensive investigation into the fauna of a spruce wood. He also calculated a daily production of excrements for collembolans, mites and enchytraeids. In the same year Tragardh (1928) published a study on the soil fauna of a Swedish wood.

Bornebusch (1930) published a detail study of the soil fauna of Danish forests. Besides reporting the quantitative results of some of the dominant groups, such as earthworms, mites, collembolans, etc., he dealt at length, the results concerning the role of soil fauna in litter decomposition.

Ulrich (1933) studied the litter fauna of a spruce wood with slow decomposition and a mixed beech-oak forest with a fairly good rate of decomposition. He related the fluctuations in numbers of fauna with the data on the climate. In the same year in Germany, Butovitsch and Lehner (1933) and Volz

(1934) investigated from mor and mull soils. Some years later, Fourman (1936, 1938, 1939) studied the significance of soil fauna in litter decomposition. He described the humification of tree-stumps and critically emphasized the stumps as hiding and gathering points for the soil fauna.

From the tropical Panama, Williams (1941) studied the soil fauna of a primeval forest. His investigation yielded numerous new genera and species. He also made attempts to discuss the ecological characteristics of some of the dominant groups.

Eaton and Chandler (1942) studied the composition of the fauna of different soil types in New York. The works of Hope (1943) and Pearse (1946) showed that American fauna resembled greatly the European forms, quantitatively and taxonomically.

Forsslund (1943) published an extensive study of the fauna of Swedish forest soil. He calculated the density, frequency and dominance of various species of soil fauna occurring in scotch pines and spruces with different undergrowths.

Jahn (1944) studied the fauna of the soil in pine aforestation of different ages in Austria. She related climatic factors as an influence on the fluctuation in the total numbers of the soil fauna, their development and vertical movement.

Strickland (1945, 1947) published two investigative reports on the fauna of the soil of cocoa plantations and compared it with that of native woods and a savannah biotope in

Trinidad. He also made attempts to show the influence of human activities on soil fauna.

Analysis of the faunal composition of a beech forest floor in Holland was made by Drift (1951). This publication deals extensively with the population dynamics over the seasons and vertical distributions of various soil faunal groups as was observed in such undisturbed forest floors.

Murphy (1955) studied the ecology of the fauna of forest soils. Di Castri (1963) published a work on the fauna of a broad-leaved forest floor in Chili. In the same year, Drift (1963) compared the soil fauna of a forest in Suriname with that of a plot of cultivated land. Maldague and Hilger(1963) studied leaf litter fauna of an equatorial rain forest. Greenslade and Greenslade (1968) investigated the density and vertical distribution of the soil and litter fauna of a lowland rain forest and grassland in the Solomon Islands.

McColl (1974) made a preliminary survey of soil faunal composition of six different forest types of West Coast, South Island. In Australia, Plowman (1979, 1981a) made an investigation into the litter and soil fauna of sub-tropical forests. She described the ecological characteristics of the Australian soil fauna and concluded resemblances with those of similar forest soils of the world.

More recently, Streit (1982) investigated a mixed beech-oak-pine forest in Switzerland for its arthropod popula-

tions. Similarly, Poursin and Ponge (1984) studied the microarthropod populations of forest humus in France.

Numerous literature on the forest soil fauna of Russian sub-continent are also available. Recent ones of importance are those of Ghilarov and Perel (1971) and Ghilarov (1979). These works include investigative results on the soil fauna of mixed coniferous-deciduous broad-leaved forests of Soviet Far East and beech-fir mixed forests of Caucasus. Recently, Nadvornyj (1983) studied the ecological aspects of soil mesofauna in the Ukrainian forest steppe.

From the Indian sub-continent, Singh and Singh (1975) and Singh and Mahajan (1981) made ecological investigation of soil and litter fauna of tropical deciduous forests. From the evergreen forests of Kashmir, Raina et al. (1981) and Rishi (1981) described the ecological characteristics of the soil and litter fauna. Hazra (1982) made a comprehensive report of the soil and litter faunal composition of forests of the Silent Valley in Kerala.

In addition to these, Reddy and Alfred (1977) and Hattar and Alfred (1984) studied the population fluctuations and community structures of soil arthropods from the sub-tropical pine forests of Meghalaya, North-East India. Very recently Sarkar (1984a) studied the soil microarthropod community of a deciduous forest in Tripura

1.5. Literature on Collembola

After the classification of the soil fauna according to their body sizes by Drift (1951) and Wallwork (1970), literature now exists for microfauna, mesofauna and macrofauna. However, the bulk of soil faunal literature is devoted to the studies of meso- or micro-fauna in general, and Collembola and Acarina in particular.

Collembola usually takes second place only to the acari among the air-breathing fauna of the soil. Ecological studies on Collembola are numerous from different parts of the world. Some of the important ones, particularly from the forest soils or related habitats are those of Davis (1928), MacLagan (1932), Ford (1937, 1938), Glasgow (1939), Baweja (1939), Forsslund (1945), Weis-Fogh (1948), Schaller (1949), Strenzke (1949), Drift (1951), Salt (1952, 1955), Macfadyen (1952, 1963), Bellinger (1954), Murphy (1955), Kubiena (1955), Sheals (1957), Balogh (1958), Haarløv (1960), Cragg (1961), Kuhnelt (1961), Poole (1961, 1963), Dhillon and Gibson (1962), Milne (1962), Kitazawa (1962), Davis (1963), Hale (1963, 1966, 1967), Christiansen (1964), Torne (1965), Ogino *et al.* (1965), Marcuzzi (1966), Naglitsch (1966), Poinsot (1966), Whitkamp and Crossley (1966), Niijima (1966a,b, 1971, 1975), Huhta *et al.* (1967, 1969), Wood (1967), Tanaka (1967, 1970), Tamura (1967, 1976), Joosse (1969, 1970, 1971, 1973, 1975, 1981), Usher (1969, 1970), Vannier (1970) Butcher *et al.* (1971), Willard (1973), Takeda (1973, 1976, 1978, 1979a,b, 1983, 1984), Blackith (1974), Fjellberg(1975), Kaczma-

rek (1975), Joosse and Testerink (1977), Pomeroy (1977), Leinaas (1978, 1981, 1983), Wiggins et al. (1979), Mertens and Blancquaert (1980), Testerink (1982), Hagvar (1982), Huhta and Mikkonen (1982), Mertens et al. (1982), Wolters (1983), and Seastedt and Crossley (1984).

Systematics of Indian Collembola are known through the works of Imms (1912), Carpenter (1917), Yosii (1966), Prabhoo (1971a,b), Mitra (1973, 1976a,b, 1982), Mitra and Choudhuri (1973), Tyagi and Baijal (1979), Prabhoo and Muraleedharan(1980) and Mari Mutt and Bhattacharjee (1980).

Ecological studies on Indian Collembola are those of Choudhuri (1960, 1961, 1962, 1963a,b), Choudhuri and Roy (1965, 1967, 1970, 1971a,b,c, 1972), Singh and Mukharji (1971, 1973), Singh and Pillai (1973, 1975, 1981), Singh and Singh (1975), Choudhuri and Banerjee (1975), Prabhoo (1976), Gupta and Mukharji (1976a,b, 1978), Reddy and Alfred (1977, 1978a,b), Singh and Singh (1978), Hazra (1978), Choudhuri et al. (1978), Mitra et al. (1978), Bhattacharya and Raychaudhuri (1979), Reddy (1980, 1981) Vatsauliya (1981), Pai and Prabhoo (1981), Raina et al. (1981), Rishi (1981), Haq et al. (1981), Veeresh et al. (1981), Singh and Mahajan (1981), Mahajan and Singh (1981), Mukherjee and Roy (1981), Hazra and Choudhuri (1981), Mitra et al. (1981), Barlong and Alfred (1984), Kurup and Prabhoo (1984), Panda and Guru (1984), and Roy and Banerjee (1984).

1.6. Literature on Acarina

Acarina or mites are numerically the most abundant faunal groups in most soils. Some of the important ecological studies on soil acari, particularly the oribatei, are those of Weis-Fogh (1948), Drift (1951), Macfadyen (1952), Karppinen (1955), Haarløv (1955, 1960), Sheals (1957), Wallwork (1958, 1959, 1967, 1970, 1983), Eitminaviciute (1959), Woolley (1960), Tarras-Wahlberg (1961), Nef (1962), Davis (1963), Madge (1964), Hayes (1965), Berthet and Gerard (1965), Block (1965, 1966a,b), Harding (1967), Wood (1967), Marshall (1968), Reeves (1969), Popp (1970), Fujikawa (1970a,b, 1974), Metz (1971), Usher (1971, 1975), Butcher et al. (1971), Anderson (1971, 1978), Hammer (1972), Luxton (1972, 1975, 1981a,b,c,d,e), Price (1973, 1975), Pande and Berthet (1975), Price and Benham (1976), Mitchell (1977, 1978, 1979), Behan et al. (1978), Aitchison (1979a), Thomas (1979), Baath et al. (1980), Plowman (1981b,c), Athias-Binche (1981) and Karg (1982).

Our knowledge on the systematics of Indian soil acari, with particular reference to the oribatid mites, are due to that of Pearce (1906), Ewing (1910), Jacot (1933), Baker (1945), Aoki (1965), Prasad (1965, 1974), Bhaduri and Raychaudhuri (1967, 1968), Chakrabarti and Bhaduri (1972), Chakrabarti et al. (1972, 1973), Hafeez-Kardar (1972, 1974), Bhattacharya et al. (1974), Bhaduri et al. (1974), Bhaduri et al. (1975), Haq(1978), Pramanik and Raychaudhuri (1978), Gupta (1981) and Mohanasundaram (1982).

However, acarine ecology in India is only of recent interest as evident from Mukharji and Singh (1970), Singh and Mukharji (1971), Singh and Pillai (1975, 1976), Choudhuri and Banerjee (1975 , 1977) , Singh (1978) , Bhaduri and Raychaudhuri (1978), Choudhuri et al. (1978), Choudhuri and Pande (1979, 1982), Joy and Bhattacharya (1981), Sanyal (1981), Sanyal and Bhaduri (1982), Bhattacharya and Chatterjee (1984), Sanyal and Sarkar (1984) and Sarkar (1984b).

1.7. Literature on "Other Arthropods"

Accounts of soil arthropods other than Collembola and Acarina are also provided in the general studies of soil fauna by Drift (1951), Kuhnelt (1961), Kevan (1962), Wallwork (1970, 1976) and Babbatt (1983), as well as in the collection of papers edited by Doekson and Drift (1963), Burges and Raw (1967), Graff and Satchell (1967), Phillipson (1970), Vanek (1975), Edwards and Veeresh (1978), Veeresh (1981) and Lebrun et al.(1983). In addition to these, a brief review of some of the major groups of soil arthropods other than Collembola and Acarina, with particular reference to the Indian works, are as follows.

Protura and Diplura:

Proturans and diplurans are often neglected by soil zoologists because they are rarely collected in large numbers. Notable contributions on the ecological studies of these groups from different habitats are Tuxen (1949, 1965), Raw (1956),

Engelman (1961), Kuhnelt (1961), Nosek (1975, 1977, 1982), Gunnarsson (1980), Tomlin and Miller (1982) and Nadvornyj (1983).

From Indian soils, Choudhuri and Roy (1970) reported the presence of Protura in some districts of West Bengal. Singh and Mukharji (1971) listed the different species of Diplura occurring in and around Varanasi in Uttar Pradesh. Prabhoo (1972) reported the different species of Protura from South India, notably Kerela. Reddy (1980) recorded both proturans and diplurans from the Pine forest soils of Meghalaya. More recently, Ghaisas and Ranade (1981) recorded Diplura from Poona.

Hemiptera/Homoptera:

Indian works on this group has been chiefly directed as pests of agricultural crops, notable among them being Ayyar and Ramakrishna (1930, 1940), Lal and Singh (1947), Channa Basavanna and Rajagopal (1978). Reddy (1980) recorded the hemipterans in the pine forest floor of Meghalaya. Recently, Ghosh (1981) gave an account of the ecology of the subterranean aphids of India.

Isoptera (Termites):

Termites form a dominant group among soil living organisms, particularly in the warmer regions of the world. Numerous literature exist on this group perhaps because of their role as destructive pests and contribution to soil fertility. As far back as 1886, Drummond suggested that in the tropics,

the termites play a part in improving and preserving soil fertility equal to that of earthworms, as described by Darwin (1881) for temperate countries. Recent works on termites are those of Hesse (1955), Kemp (1955), Nye (1955), Robinson (1958), Maldague (1959), Lee and Wood (1971), Arshad et al. (1982) and Anderson and Wood (1984).

An excellent review of recent advances in termite research in India has been done by Sen-Sarma (1981). Earlier, Roonwal (1958) reviewed the extent of termite research in India, particularly between the period 1947-1957. Most recent ecological works on Indian termites are those of Chhotani (1981) and Roonwal (1981).

Hymenoptera (Formicidae):

Ants are one of the best known social insects. Myrmecology or the science of ant study had been in progress since the middle of the 18th century. Hence, innumerable literature exists on the study of ants inhabiting the soils. However, the most recent ones are those of Elmes (1978), Petal (1980), Goesswald (1981), Elmes and Wardlaw (1982).

A brief review of the study of ants in India had been given by Verghese and Veeresh (1978). Early workers in Indian myrmecology include Rothney (1890), Wroughton (1892), Bingham (1903) and Lal (1939). Recent contributors are Gupta (1963, 1964, 1966, 1968a,b, 1970), Reddy et al. (1981), Reddy and Ao (1984).

Pauropoda:

Pauropods are minute organisms, rarely more than 1-2 mm in length and are seldom found in large numbers in the soil. Pauropods had been extensively studied by Starling (1944), Lawrence (1953, 1964), Cloudsley-Thompson (1958), Leinaas (1974) and Moore (1982).

Very little information is available on Indian pauropods. Singh and Mukharji (1971, 1973) recorded these organisms from the sugarcane fields. Reddy (1980) recorded these organisms from the pine forests of Meghalaya.

Symphyla:

Notable contributions on the ecology of symphylids are those of Verhoeff (1934a,b), Michelbacher (1949), Edwards (1955, 1958, 1959, 1961), Anglade (1967) and Leinaas (1974).

From Indian soils, the symphylids have been recorded by Singh and Mukharji (1971), Vatsauliya (1981), Darlong and Alfred (1982) from different habitats. These authors have also shown that symphylids, though considered to be rare animals, were the most numerous myriapods present in the soil.

Pseudoscorpionida:

The Chelonethi or pseudoscorpions, although not very common in soils, have been ecologically well documented by Ressl and Beier (1958), Gasdorf and Goodnight (1963) and Gabbutt(1967).

From India, pseudoscorpions have been collected from different habitats by Choudhuri and Roy (1970), Singh and Mukharji (1971), Reddy (1980) and Vatsauliya (1981).

Chilopoda and Diplopoda:

Some of the recent notable ecological works on these groups are those of Bocock and Heath (1967), Saito (1967), Wallwork (1970), Davis and Sutton (1977), Davis et al. (1977), Geoffroy (1981), Enghoff (1983), Nadvornyj (1983), Kokhiya (1983), Kime and Wauthy (1984), Phillipson & Meyer (1984) and Snider('84).

The early works of Pocock (1892), Silvestri (1916) and Attems (1937) were limited to taxonomical descriptions of some of the Indian and oriental millipedes. Recent works on Indian millipedes are those of Rangaswamy and Channa Basavanna (1969), Rangaswamy et al. (1978a,b), Bano and Krishnamoorthy (1978,1981) and Mukhopadhyay and Saha (1981). No ecological data is available on Indian Chilopoda except that they had been recorded as components of soil fauna by Reddy (1980), Vatsauliya (1981) and others.

Isopoda (woodlice):

A considerable amount of literature exist on the ecological studies of soil-dwelling isopods from different parts of the world, and some of these include Sutton (1972), Davis and Sutton (1976) and Nadvornyj (1983). However, no ecological data exist on Indian isopods, except perhaps the records of David

(1965, 1978) as pests of sugarcane plantations in Tamil Nadu and Reddy (1980) as component of pine forest soil arthropods in Meghalaya.

Coleoptera:

Recent ecological studies on soil-dwelling coleopterans include Evans (1969), Greenslade (1972), Aitchison (1979a), Peck and Forsyth (1982), Nadvornyj (1983), and Dennison and Hodkinson (1984a, b).

Important studies on Indian soil-dwelling coleopterans and their white grubs are those of Stebbing (1914), Fletcher (1917, 1920), Ayyar (1922), Trehan (1929), Mathur and Singh (1959), Siddappaji and Channa Basavanna (1978), Viswanath et al. (1978), Tayade and Raodeo (1978), Yadava et al. (1978), Dutta and Sengupta (1981). Most of these studies, however, are limited to the reports or records of beetles and their grubs as silvicultural and agricultural pests.

In addition to the foregoing literature on arthropods other than Collembola and Acarina, ecological studies of recent importance for spiders (Uetz, 1975; Koponen, 1975, 1977; Waldof, 1976), diptera (Aitchison, 1979c; Mollon, 1982; Hovemeyer, 1984) and insect larvae (Nabialczyk-Karg, 1980) are also available from different parts of the world. However, similar studies of soil fauna from Indian sub-continent are greatly wanting.

1.8. "Jhum" (Shifting cultivation) in North-East India and the soil fauna

The prehistoric origin of shifting cultivation is credited to the Neolithic period about 8000-7000 B.C. on the strength of archaeological evidences, when human society changed from food-gathering to food-production (Sharma, 1976). Therefore the practice of burning slash to prepare swidden is not less than 10,000 years (Solheim, 1967) but man's use of fire to clear and alter natural communities for other reasons is much older (Sauer, 1967; Stewart, 1970; Pullan, 1975; Scott, 1977). This ancient form of slash and burn agriculture, known differently in different tribal belts (who practice this type of traditional cultivation), is still predominant among the hill people of the humid tropics and sub-tropics of the world.

Known as "Jhum" or "Jhumming" in North-East India, the cycle of this primitive agricultural operation in this region is marked by the following stages: (1) selecting a forested hilly land; (2) clearing the forest tract by cutting or slashing the vegetation; (3) allowing the slashed vegetation to dry; (4) making fire line and burning the dried forest into ashes; (5) collecting and clearing unburned logs and branches; (6) worship and sacrifice; (7) dibbling and sowing of seeds of various crops; (8) weeding (several times during a cropping period); (9) watching and protecting the crops; (10) harvesting; (11) thrashing and storing; (12) merry making and (13) fallowing, i.e. abandoning for natural regeneration of the forest for a considerable

number of years after which the cycle is repeated. In its traditional form, the jhum cycle (the intervening fallow period after which the forested fallow land is similarly recultivated) used to be 20-30 years, but has now been reduced to 4-5 years due to increased population pressure.

The pattern of jhum at higher elevation of the Khasi Hills of Meghalaya, as around Shillong, is a modification of the typical type as outlined above. Here the destruction of the forest (dominated by Pinus kesiya Royle ex Gordon) is only partial. Instead of complete clearing of the forest, only the undergrowths and lower branches of the trees are slashed and arranged over the land that has been prepared into parallel ridges and furrows. During the months of late February to early March, a thin layer of soil is placed over the dried plant biomass that were arranged over the ridges and burned. Organic manure, in the form of cowdung, is also applied in the soil before planting the crops (Plates : 1-9).

A mixture of crops are grown together in the same field. Soon after the burn and a few weeks before the onset of monsoon, the tuber crops like Solanum tuberosum, Ipomoea batatus, and Colocasia antiquorum are planted on the ridges. Sowing of cereal (Zea mays), legume (Phaseolus vulgaris) and a few cucurbits (Cucurbita maxima and Cucumis sativus) are done just after the onset of monsoon. Along each ridge, usually three distinct rows of sowing is done through dibbling with a mixture of both Solanum tuberosum and Zea mays mixed together. Planting of Colo-

PLATE : 1

THE VIEW OF SHILLONG FROM A PART OF the Laitkor Forest, Close to the Study Area.

The small branches, twigs & leaves of slashed vegetation arranged in rows & allowed to dry.

PLATE : 2

A farmer is arranging the slashed vegetation into rows over the ridges.

PLATE : 3

Soil-covered dry vegetation arranged in ridges & furrows, ready for burning

PLATE : 4

The dried vegetation is being burnt.

PLATE : 5

As the plot looks just after burning.

PLATE : 6

The unburned vegetation is being collected for reburning.

PLATE : 7

A Jhum plot ready for cultivation.

PLATE : 8

An old Jhum plot (fallow) under Preparation for recultivation.

PLATE : 9

casia antiquorum is confined generally to the top and bottom part of each ridge and the cucurbits are sown at random, but widely scattered on the ridge. Phaseolus vulgaris is sown around the pine trees which provide support to it. After the harvest of the tuber crops in July-August, a winter crop of Solanum tuberosum is sown along the ridges. Harvesting of Zea mays and Phaseolus vulgaris is done in September-October, after which Brassica oleracea seedlings are planted along with the winter crop of Solanum tuberosum. Harvesting of these winter crops are done in November and then the field is left uncultivated between December to March, during which the field is prepared following similar procedures (slashed vegetations are collected from adjoining forest), if second year of cultivation is to be done; otherwise the field is abandoned for regeneration of natural vegetation (Mishra and Ramakrishnan, 1981).

Controlled burning, which is prevalent in different parts of the world, is an accepted and widely used forest management practice. It is used chiefly to reduce fire hazard and secondarily, to create conditions appropriate for the establishment of future forest stands (Ahlgren and Ahlgren, 1960; Rowe, 1970; Kilgore, 1972, 1973, 1976; Viereck, 1973).

In slash and burn agriculture, although fire performs the necessary function of clearing the new swidden and converting slash to fertilizing ash, it has three less desirable side effects: (1) certain nutrients are lost from the system as volatiles (Lewis, 1974); (2) soil surfaces are exposed to possible

erosion by water and wind; and (3) changes to the physical and chemical properties of soil are initiated. Destruction of the original vegetation cover and creation of an entirely different microclimatic and radiation conditions at ground level also results. These effects, however, are part of the original reason for felling the forest.

Such adverse effects from burning and the effects of fire on ground and soil animals do exist (Rice, 1932; Heyward and Tissot, 1936; Pearse, 1943; Ahlgren and Ahlgren, 1965; Buffington, 1967; Huhta, 1971; Metz and Farrier, 1971a,b; Vlug and Borden, 1973; Christensen and Kimber, 1975; Merrett, 1976; Lussenhop, 1976; Roesgaard and Lindhardt, 1979; Kuebelboeck, 1982; Majer, 1984).

Further, it is a tradition to criticize shifting cultivation as a waste of land and human resources (FAO, 1957). However, recent investigations indicated several ecological benefits of shifting cultivation, including advantages of intercropping and forest fallow in pest control and maintenance of soil quality (Jaiyebo and Moore, 1964; Clarke, 1976; Wilken, 1977), the favourable energy input to energy output ratio (Rappaport, 1971), and the rich abundance of useful plants available from forests under fallows (Arnason et al., 1980). And yet, modern shifting agriculture is not without ecological problems. Recent pressure for land has led in turn to sedentation (intensification of land use through establishment of permanent villages), degradation of habitats, decreasing yields, etc. (Clarke, 1976).

Thus, shifting agriculture is now alternately condemned and praised. This peculiar traditional sustaining activity of a section of humid tropical population continues to draw the attention of investigators from different parts of the world (Freeman, 1955; Schlippe, 1956; Bartlett, 1956; Conklin, 1957; Pelzer, 1957; Carneiro, 1960, 1961; Webster and Wilson, 1966; Denevan, 1966, 1971; Harris, 1971; Odum, 1971; Watters, 1971; Sanchez, 1973, 1976; Scott, 1974; Manshard, 1974; Zinke et al., 1978; Arnason et al., 1982; Montagnini and Jordan, 1983).

Literature on the jhum system (shifting cultivation) of India in general, and North-East India in particular, are limited to the socio-economic, socio-cultural, soil nutrients, low yields, secondary plant successional status (Pakem et al., 1976; Borthakur et al., 1978; Ramakrishnan et al., 1978; Ramakrishnan and Toky, 1978, 1981; Toky and Ramakrishnan, 1981a,b; 82; Mishra and Ramakrishnan, 1981, 1983a,b) and microbial populations (Deka, 1981). In comparison, the few data which exist on the ecological studies of soil fauna of jhum, and the role of soil fauna in the recuperation of the soil under such conditions of stress, are found in Vatsauliya and Alfred (1980), Vatsauliya (1981) and Darlong and Alfred (1982, 1984).