

**STUDIES ON THE ECOLOGICAL IMPACT OF SHIFTING  
AGRICULTURE (JHUM) ON FORESTED ECOSYSTEM**

( ABSTRACT )

**OM PARKASH**

DEPARTMENT OF BOTANY  
SCHOOL OF LIFE SCIENCES



SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF  
THE DEGREE OF  
**DOCTOR OF PHILOSOPHY**

To



**NORTH-EASTERN HILL UNIVERSITY  
SHILLONG, INDIA**

**OCTOBER-1980**

\* \*\* >  
Dec. No &  
Dec. hr  
Dist.  
Class  
Lab

16/5/24

«»»e'

# STUDIES ON THE ECOLOGICAL IMPACT OF SHIFTING AGRICULTURE (JHUM) ON FORESTED ECOSYSTEM

## ABSTRACT

Slash and burn agriculture (locally called 'Jhum') is a predominant form of agriculture in north-eastern hill regions of India, and supports about 1.6 million tribal population over an area of 0.426 million hectares. This practice involves felling the forest vegetation, burning the dried biomass, mixed cropping of 8-13 species for a period of 1 or sometimes 2 years and then reverting the land to its natural vegetation (forested fallow) so as to allow restoration of soil fertility. The present study on 'jhum' was done at Burnihat which is located in the Khasi hills of Meghalaya at 26.0°N and 91.5°E. The climate is hot and humid with an average rainfall of 220 cm. The soil is of lateritic origin (Oxysol) with pH ranging from 5-7. Here jhum is practised chiefly by one of the tribes of Meghalaya, namely, the 'Garos'.

### (i) Cropping and yields in agricultural systems:

Along with 'jhum' some sedentary rice cultivation and terrace cultivation on the hill slopes are also practised. The 30 year jhum cycle (the fallow period before the land is again cleared) has advantage over the 10 or 5 year cycle, in that apart from higher yield, monetary output/input ratio under a 30 year cycle is comparatively more favourable. Further, the 30 year jhum cycle is advantageous over terrace cultivation as the latter needs heavy inputs of fertilizers. The main advantage of settled valley cultivation is the raising of crops consistent in yield year after year

from the same site. The structure and some functional aspects of these agro-ecosystem types are discussed and compared.

(ii) Energetics of agricultural systems;

From an energetic point of view, a 10 year cycle is most efficient and the output/input ratio here is 43.50 compared to 34.13 under a 30 year cycle and 23.66 under a 5 year cycle. Energetics of jhum is also compared to with valley cultivation of tice as well as mixed cropping on terraces which was tried out as an alternative to jhum. Though the efficiency of valley cultivation is closer to a 5 year jhum cycle, it is self-sustaining year after year due to natural drainage of moisture and nutrients into the valley, the only energy input being in the form of labour which is cheap. The energy putput/input xatio for terrace cultivation is very low (6.0?) due to high fertilizer input into the system and also due to labour input for preparation of the land. The various inputs of energy and outputs in the form of agricultural products in the three agro-ecosystem types have be on worked out in detail.

(iii) Soil fertility and its recovery....pattern:

The fertility changes in agro-ecosystems where vegetation is removed by slash and burn procedures, the land is planted to mixed crops for *one* year, and then left to revegetate naturally for upto 50 years (forested fallow) before the entire cycle is Repeated, have been studied. A comparison has been made between three jhum cycles of 30, 10 and 5 years. Bepletion in soil carbon continued throughout the cropping period of one year and expended upto a 5 year fallow. This could be one of the reasons against a

short jhum cycle alongwith a similar pattern in depletion of nitrogen. Available phosphorus build up in the fallows also started only beyond a 5 year fallow period with rapid increase in 10, 15 and 50 year fallows. Cationic concentration in the soil also rapidly declined in the early phases of regrowth of vegetation. This decline was most pronounced for potassium due to the fact that Dendrocalamus ham-Mtonii is a heavy accumulator of this nutrient. Since this bamboo species domxnates the fallow upto 20 years, potassium bnild up in the soil was observable only at this stage. It is suggested that this species plays an important role in conservation of this nutrient. In a 50 year fallow, low levels of calcium and magnesium were maintained with rapid depletion of both with depth which is in contrast to that of potassium and phosphorus. In general, short jhum cycles of 5 year permit only low levels of soil fertility with very poor recovery during the fallow period. The significances of these results are discussed,

(iv) Hydrology and nutrient losses;

Subsequent to slash and burn of the forested fallow and during cropping, the system loses its capacity to hold the nutrients. Various losses occur through wind blow of ash and also through increased run-off and percolating water. The chemistry of the ash and run-off and percolating water is related to the length of the jhum cycle due to the type of vegetation that is slashed and burnt. The run-off and percolation losses of water and sediment during cropping increased with shortening of the jhum cycle. Since percolation losses are fairly high due to porous soil, terracing of land

as suggested by some as an alternative to jhum is not an ecologically sound one. Drastic reduction in losses of sediment and nutrients occurred in a 5 and 10 year fallows. The shortening of the jhum cycle to 4-5 years has adversely affected the biogeochemical and hydrologic cycles.

(V) Secondary succession, biomass, litter production and productivity:

The secondary successional pattern of plant communities subsequent to jhum upto 50 year fallow and the biomass, productivity and litterfall patterns during succession upto a 20 year fallow period were studied. The early weedy colonizers vary depending upon the type of vegetation that is slashed and burnt and the seed source available in the soil depending upon weeding practices at the time of agriculture. Dendrocalamus hamiltanii, a bamboo species, dominates the fallow between 10-20 years which is replaced by more shade tolerant dicot trees. Succession was accompanied by increased species diversity, reduced dominance and increased net primary productivity. Total inventory of aboveground biomass increased linearly with age and attained maximum value of 147.59 m.ton/ha in a 20 year fallow. The rate of accumulation of biomass increased upto 15 years of secondary growth reaching a maximum of 8.95 m.ton/ha/yr and declined in a 20 year fallow. The net primary productivity increased linearly with the age of the fallow reaching a maximum of 17.99 m.ton/ha/yr. Litterfall showed a significant positive correlation with the age of the fallow and total standing biomass of the fallow, reaching a maximum of 9.69 m.ton/ha/yr collected in

a 20 year stand.

(vi) Nutrient cycling %

Accumulation of bioelements, their rate of uptake and release through litterfall were measured in successional stands upto 20 year. Concentration of nitrogen, phosphorus and potassium was higher in living biomass than in the litter. Dicot trees were found to be rich in calcium, bamboo (Dendrocalamus hamiltonii) in potassium and herbaceous species in phosphorus. The total inventory of bioelements increased linearly with increase in the age of the fallow and attained a maximum level per hectare of 489 kg nitrogen, 64 kg phosphorus, 13159 kg potassium, 440 kg calcium and 226 kg magnesium in a 20 year fallow. In this fallow 8 to 73 % of the various elements of budget were allocated to the bole compartment. Potassium was the most abundant element followed by nitrogen. In fallows of 10 to 20 years, bamboo alone contributed 10 to 45% nitrogen, 44 to 49% phosphorus, 54 to 60% potassium, 16 to 19% and 34 to 39% magnesium of the total budget. Maximum annual rate of accumulation of nitrogen (25.087 kg/ha) occurred in 15-20 year, phosphorus (3.978 kg/ha) in 1 year, potassium (81.107 kg/ha) in 10-15 year, calcium (28.504 kg/ha) and magnesium (12.499 kg/ha) in 15-20 year fallows. Potassium showed the highest rate of accumulation and it was 1.3 to 3.3-fold higher than that of calcium and magnesium collectively. Annual rate of nutrient uptake increased consistently with the age attaining a maximum rate between 15-20 years. The enrichment ratio was maximum for phosphorus and potassium

indicating their fast rate of conservation in the standing biomass. Maximum depletion of soil nutrient pool occurred between 5-10 year of growth period. Annual return of nutrients through litterfall increased with the age of the fallow showing maximum return in a 30 year fallow,

(vii) general, conclusions and consideration;

On the basis of this study the various reasons against a short jhum cycle of 4-5 years have been quantified, it is also suggested that terracing is not an ecologically viable alternative to jhum. In fact, in a situation as it exists in the north-eastern hill region which has a very high rainfall of over 200 cm in most of the areas reaching as high a value as 1350 cm per year at selected spots like Cherrapunji, most of which comes during the monsoonic period of 3-4 months, with very steep topography and with high percolation values due to extremely porous soil, cereal cultivation in any form should be avoided. This is more true when one realizes that much of the nutrient losses from the system occur during the *parly* phase of cropping at the time of sowing and before crop establishment and at the time of harvest when the plant cover is removed and the soil is again disturbed. Plantation crops like rubber, coffee or tea which have been tried with success on an experimental scale in selected areas and horticultural crops of various kinds for which this region is very well suited seems to be the direction in which the economy of this region should be developed.

..... JUSjN\*  
<t\*M>y.. JV ~.....  
<t<r>r .... ,«\_|| n-

**STUDIES ON THE ECOLOGICAL IMPACT OF SHIFTING  
AGRICULTURE (JHUN) ON FORESTED ECOSYSTEM**

**OM PARKASH**

**DEPARTMENT OF BOTANY  
SCHOOL OF LIFE SCIENCES**

**SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF  
THE DEGREE OF  
DOCTOR OF PHILOSOPHY**

To



**NORTH-EASTERN HILL UNIVERSITY  
SHILLONG, INDIA**

**OCTOBER-1980**

**G3\^^)035M\6**

ts<sup>T</sup>HHU Library

y.

S.:b. *H? d'jiz* by...  
Cata. b, \_\_\_\_\_,,  
Transcribed by....^

Grams: NEHU

Phones: Off 3390  
Res 6943



# North - Eastern s5|p5 Hill University

P. S. Ramakrishnan  
M.Sc, Ph.D., F.N.A., F.A.Sc, F.N.A.Sc. ~  
Professor of Botany & Dean of the School V. W)

DEPARTMENT OF BOTANY  
SCHOOL OF LIFE SCIENCES  
SHILLONG - 793003

I certify that the thesis entitled  
"STUDIES ON THE ECOLOGICAL IMPACT OF SHIFTING  
AGRICULTURE (JHUM) ON FORESTED ECOSYSTEM" submitted  
by Mr. Om Parkash 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.

**Date:** 30<sup>th</sup> May 2010 . ^Jl^fcJta-\*M

Place: Shillong

Signature of the Supervisor

## ACKNOWLEDGEMENTS

At the very outset I would like to express my heartfelt gratitudes towards my revered teacher Dr. P.S. Eamakrishnan, M.A., Professor in Department of Botany, North-Eastern Hill University, Shillong, who guided me in this research work with profound interest and devotion. Without his incitement and able guidance this investigation would not have been possible.

I am highly thankful to Professor Rodger Mitchell, Ohio State University, U.S.A., who always evinced a keen interest in my work. The fruitful discussions I had with him on the various aspects are gratefully acknowledged.

I also benefitted immensely from Dr. R.S. Tripathi, Reader in Botany, who participated actively in individual and group discussions. I owe thanks to him.

Thanks are due to Dr. R.R. Rao, Reader in this Department and Mr. K. Haridasan, research scholar for their ready help in identification of plants.

The encouragement given to me during the writing phase of my thesis by Dr. R.K. Kohli, formerly Pool Officer in this Department is gratefully acknowledged.

My sincere thanks to Professor R.R. Mishra and Dr. Avtar Singh and other staff members of the Department for their kind cooperation and encouragement.

It is my utmost pleasure in thanking Mr. P.S. Ingty, Director, Soil Conservation Department and Mr. B.N. Das, Chief Conservator of Forests, Meghalaya for rendering their kind help in various ways during my research period. My sincere thanks are due to the scientists of ICAR Complex, Shillong for their cooperation in the field work and discussions of various research problems.

The lab had become my second home and the feeling of friendliness and informal atmosphere among my research colleagues lessened the temporary setbacks that are characteristics of any research project of this type. My hearty thanks to all of them for sharing my difficulties and for constant help in the laboratory.

The patience with which my parents, brother and sisters bore this period of research is also remembered with gratitude and words fail me to convey my feeling for their deep love and affection. To Mrs. P.S. Hamakrishnan, I am deeply grateful, whose contribution towards the success of this endeavour is immense. Special words of thanks are also due to my good friends namely Mr. Harish Chander Malik and Mr. Jasbir Singh Grewal.

The assistance rendered during statistical analysis by Miss Gitashri Das, Statistician of the Department and doing field work by Mr. Latison Momin is gratefully acknowledged. To Mr. Vijay Das for photography and Mr. M.H. Barbhuiya for drawing, I am highly thankful.

I am specially grateful to Miss Meera Shabong for her active help in typing the thesis.

Last, but not the least I express my thanks to the University Grants Commission for providing me the fellowship through North-Eastern Hill University for the tenure of my research.

(OM PASKASH)

Department of Botany  
School of Life Sciences  
North-Eastern Hill University  
SHILLONG 793014

Dated October 30 , 1980.

## CONTENTS

	Page (s)
PREFACE	I-
INTRODUCTION	i-a6
CHAPTER 1 : CROPPING AND YIELDS IN AGRICULTURAL SYSTEMS OF THE NORTH-EASTERN HILL REGION OF INDIA.	A7-52.
CHAPTER 2 : STUDIES ON ENERGY BUDGET IN SOME AGRO-ECOSYSTEM TYPES OF NORTH-EASTERN HILL REGION OF INDIA-	Bi-Tt
CHAPTER 3 : SPECIES DIVERSITY, BIOMASS, LITTERFALL AND PRODUCTIVITY PATTERN DURING SECONDARY -SUCCESSION SUBSEQUENT TO SHIFTING AGRICULTURE (JHUM) IN NORTH-EASTERN INDIA.	17-1°5
CHAPTER 4 : SOIL FERTILITY STATUS OF HILL AGRO-ECOSYSTEMS AND RECOVERY PATTERN AFTER SLASH AND BURN AGRICULTURE (JHUM) IN NORTH-EASTERN INDIA.	106-i^X.
CHAPTER 5 : RUN-OFF AND INFILTRATION LOSSES RELATED TO SHIFTING AGRICULTURE (JHUM) IN NORTH-EASTERN INDIA.	IM*-»W
CHAPTER 6 : NUTRIENT CYCLING IN SUCCESSIONS COMMUNITIES DEVELOPING AFTER SLASH AND BURN AGRICULTURE (JHUM).	»6*-m
GENERAL CONSIDERATIONS AND CONCLUSIONS	×%H2×o
LITERATURE CITED	loi-;tl<l
APPENDIX	

## PREFACE

This study was undertaken at Burnihat located at an altitude of 100m in the Khasi hills of Meghalaya in order to study the hill agro-ecosystems and more particularly to measure the impact of slash and burn agriculture (locally called 'jhum') which is the predominant agricultural practice in the entire north-eastern hill region of India.

A number of aspects like hill agro-ecosystem, structure and productivity and energetic efficiency have been studied and form., the topic of discussion in chapters 1 and 2. This is followed in chapter 3 by the analysis of vegetation during secondary succession in jhum fallows with respect to its structure, biomass and productivity. Chapter 4 deals with the detailed study of changes in nutrients in soil after burn and during cropping period of one year of jhum. This is placed in the context with the nutrient recovery patterns during forested fallow development upto an age of 50 years. Chapter 5 deals with hydrology and various types of losses of sediment and nutrients from agro-ecosystem. It also deals with the hydrology and the losses from the ecosystem during development of the fallows. Chapter 6 concerns itself with nutrient cycling through the entire process of jhum upto a forested fallow period of 20 years.

The thesis starts with a General Introduction and is concluded with a Chapter on "General Considerations and Conclusions'\*. The conclusions drawn are chiefly based on the present studies. Apart from this general discussion, each Chapter has its own discussion of results and summary. The various chapters have been prepared keeping in view the eventual publication of papers in different journals. All literature cited in the text is brought together at the end.

...\*-) The various studies on jhum have been done particularly keeping in mind the impact of the shortening of the jhum cycle from an ecologically more favourable situation of 30 years to as short a period as 4-5 years, as a consequence of reduction in acreage and increase in population pressure. Thus, wherever feasible a 30 year jhum cycle has been compared and contrasted with a 10 and 5 year cycle.

GENERAL INTRODUCTION

## GEJHERAL INTRODUCTION

Slash and burn agriculture is practised on a wide range of *apil* types, slashing varied vegetational types, and by people of widely different origin and culture that it shows great variations in the types of crops grown, the length of the cropping and fallow period, and the method of cultivation itself. But the system is universally characterized by (1) partial or complete clearing of the vegetation by cutting and burning (2) cultivation of pure or mixed crops, and (3) the abandonment of the plot to fallow regeneration after the exhaustion of the soil fertility. A short period of cropping generally alternate with a longer period of fallow with exclusive use of human energy for all the steps of the agriculture. It is one of the oldest of all the agricultural systems, which indicates that it must be or has been until recently, more or less in equilibrium with the environment.

It is frequently called as 'slash and burn' agriculture, though the term 'swidden' is preferred by some anthropologist (Exwall, 1955)\* The practice is also referred to by a number of local names, among which 'milpa' from Central America, 'chena' from Ceylon, and 'xaingin' from

the Philippines are common. In the north-east India and Bangladesh, the system is called as •Jamm<sup>1</sup>. The nomenclature of the system has been thoroughly discussed by ConJclin (1957)\*

Regional differences :

Of the three great continental regions of shifting agriculture in the tropics, Africa is the largest having a great variety of natural conditions and cultural pattern. Its total tropical area of 5.75 million square miles, under forest, woodland and savannah holds a population of 104 million with a density of 18 per square mile (Geurou, 1953). Harroy (1949) and Worthington (1958) discussed slash and burn agriculture against a wider background of the conservation of natural resources of Africa, de Schlippe (1956) described mixed cropping on the border of the Sudan and the Congo practised by the Zande tribe. Here mixed crops including cereals (Bleusine coracana. Zea mays. Penisetum tvohoidaa. flyrata sp) pulses (Yigna unguiculat\*. Phaseolus SUSii Phaseolus lunatus). oil seeds (Ara.ahi m hytflgfimt &LMMMWM. mxlmaiAlfi.) and starchy crops (MaflIMl u^ligsima, Ipornoea batatas. Bioscorea sp, Golocasia antiquerum) are common.

Nye & Greenland (1960) gave a detail account of the system in evergreen and semi-deciduous forests in Africa. During the dry season a patch of forest is felled, dry biomass is burnt and a mixture of crops is sown by dibbling. During the growth of the crop or slightly after it has been harvested starchy crops like Cassava (Manihot utilissima), Cocoyam (Ololygona antiquorum) or Xanthosoma sagittifolium and bananas (*Musa sp*) are planted. Weeding is done twice or thrice during the cropping period. The dense mass of the developing secondary forest is soon dominated by light loving species among which *Ficus wightiana* (the Umbrella tree), Trema gnani and Mearnsia barteri are often predominant after the fields are left to regeneration of fallows. According to them, regrowth of the vegetation is rapid and three years of cropping alternating with eight years of fallow often appear to maintain fertility in the semi-deciduous forests, and 1-2 years of cropping is followed by about 10 years of fallow period in evergreen forests.

Under savannah in Africa, the soil has to be more thoroughly cleared than in a forest to get rid of roots and rhizomes of grasses. In contrast to forest the land is without cover during the dry season and it is exposed

to the early rains for at least four weeks before a fair cover is formed. The intensity of the weeds is also high particularly if Imperata cylindrica is present. When the field is abandoned it is dominated by Pennisetum sp and Imperata cylindrica if the weeding is not proper. In a year or two the tall perennial grass Andropogon gayanus appears and when in about 10 years this attains dominance, the land is considered fit to clear again.

Tropical America which has an area of 5 million square miles, has received far less scientific study. Like Africa, the system is practised both in forest and savannah regions. Cook (1921) described 'milpa' system of growing maize in Central America and concluded that 'milpa' agriculture is a stable system if the intervals between successive clearing of the same land are very long and the forest has time to restore the land to its original condition.

Carneiro (1960) studied Kuikuru Indians of Central Brazil, who subsist largely by the slash and burn agriculture of manioc (Manihot sp). He demonstrated mathematically that under a system of shifting agriculture the Kuikuru have been able to remain permanently settled and they do not have to relocate their villages periodically because of soil exhaustion. Watters (1971) describes 'conuco' agriculture

in Venezuela. Cropping is primarily for subsistence and the chief crops are invariably maize and black beans. Inter-cropping is common, with a variety of annual crops and also semi-permanent ones (Yucca or quinehoncho). Formerly stable 'cenucof system is now in a state of breakdown and shortening fallows (4-5 years) is the main cause for the breakdown.

The tropics of Asia are unlike those of Africa and America in that the density of population is ten times more as compared to other parts of the world. However, most of the population live on alluvial soils of the plains. Dobby (1950) estimated that one third of the total area used for cultivation in south-east Asia is under shifting agriculture. However, this system is practised only in forest lands and supports a density of 16 individuals per square mile. Much of these forests receive a rainfall of more than 200 cm. Conklin (1957) describes the 'Hanunoo' system in the Philippines. Forests are felled in the dry months, and after burning and clearing a mixture of crops sometimes nearly 40-50 are sown in the same plot with a system of successive harvesting.



## 6

Mey (1978) studied shifting agriculture (\*Jhmm«) in Chicagong hill tracts of Bangladesh\* The seeds of the hill fields consist of 60-80% of paddy, the rest is cotton, corn and vegetables like pulses and gourds, sesamum and chillies\* The yields of the '3 hum.<sup>1</sup> plots are very low due to shortening of the jhum cycle and the general economic situation of the farmers is bad\*

Bappaport (1971) gave a detailed account of •swidden\* agriculture of the Tsembaga<sup>r</sup> in the central highlands of Papua New Guinea\* In making garden the Tsembaga prefer to clear secondary forests rather than primary forests\* A fence is made to keep the pigs, both feral and domestic out of the garden. Trunks of the felled trees are utilized for this purpose\* The Tsembaga can name at least 264 varieties of edible plants, representing some 30 species\* The staples are taro (Colocasia esculenta) and sweet potato\* Other starchy vegetables such as yams, cassavas and bananas are of lesser importance. Sweet potatoes and cassavas are used as pig feed as well as for human consumption\* Beans, peas, maize and sugarcane are also grown, along with a number of leafy vegetables like Hibiscus sp\* The Tsembaga recognize the importance of the regenerating trees; they call them

collectively \*duk mi<sup>1</sup>, or "mother of gardens" and do not destroy them during weeding. Swine husbandry is linked with the swiddening and both these provide the Tsembaga with, on the one hand, an adequate daily energy ration and, on the other, an emergency source of protein.

In the north-eastern hill tracts of India, this practice is a source of support for 1.6 million tribal population. It is widely spread in Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Nagaland, Tripura and some parts of Assam over an area of 2.6 million ha (Mukerjee, 1975). This practice locally called as 'Jhum' consists of cutting down the forests of various successional stages on the hill slopes in the months of December and January, allowing the slash to decay for a few months and burning the slash before sowing mixed crops of about 8-13 species. The land is utilized for one or two years and then left as fallow to regenerating forest. The Jhum cycle (the fallow period before the land is again cleared) is often short ranging from 4-5 years but longer cycles from 10-30 years are also rarely available. Short cycles have adversely affected the yield of crops, the quality of the environment both in terms of soil fertility and vegetation cover.

At higher elevation (above 300 m) of Meghalaya, the practice differs from the typical form at lower elevations, in many respects. Here the vegetation type is chiefly of Pinus kfeStya. At the time of clearing the forest, only a partial felling is done in which only branches of the trees are felled and placed on the ridges of the prepared land which has ridges and furrows. Soil is put over the slash and a light burning is done and pure crop of potato, sweet potato, rice or maize is grown over the ridges sometimes there is mixing of these crops also. 2-3 crops of potato are taken in one year. The fields are used for 2-3 years and left as fallow for 5-10 years. Due to low soil fertility, some organic manure and fertilizer are added to the ridges.

Agro-ecosystem :

Under slash and burn agriculture the fertility in the soil declines rapidly with successive Seasons of cropping and this results in decrease in the yields of the crops/. In humid forest regions the yield declines faster than in dry forests and savannah regions. Tondeur (1956) reported that in the forested regions of the Belgian Congo during the second cycle of rotation of rice, groundnuts

and cassava declined 76%, 86% and 33% respectively compared to the first cycle. Nye & Stephens (1965), on the basis of fertilizer trial in forest regions of Ghana showed that during the continuous cropping for 8 years in the absence of fertilizers, the yield declined sharply but in the savannah zones of Ghana, on the average yields in the absence of fertilizers declined slowly. The yield of a second crop of maize in north Guatemala is often reduced to one half compared to the first crop (Popenoe, 1959). At Yambio Experiment Station, southern Sudan, yields of cotton, groundnuts and elmusine dropped sharply after 3 year's cropping (Anthony & Willimott, 1956).

Weeds are the major cause of declining yield under slash and burn agriculture in many parts of the world and include Sanatorium adoratum in Thailand (Zinke et. al, 1978) and TmDArata evlindrirea in Sarawak (Freeman, 1955). Cutting si, ai, (1959) reported that the yield of maize in H^saland was 4284 kg/ha when weeded four weeks after germination, but attained only 3217 kg/ha when weeded six weeks after germination. Emerson (1953), describes the influence of weeds on the 'milpa' system in tropical America, in which successive crops of maize, mixed with beans, are grown. The second crop yields less than the first, probably

because it is more weedy and therefore farmers like to clear a fresh land than to continue cropping on the old plot\* Conklin (1957) estimated that a Hanunoo farmer in the Philippines spends 300 man-Jgours per hectare in weeding the first year land cleared from primary forest and 600 man-hours on land cleared from secondary forest about 20 years old. In the south-east Asia, the forest often gives way to areas dominated by lalang (Imperata cylindrica var. major and such areas are useless for cultivation (001^11^1957-, Bedard, 1958). In Africa and America, the corresponding grasses Imperata cylindrica var. a-fricana and Imperata braziliensis are not so aggressive and are rapidly replaced by other savannah species if left abandoned (Hye & Greenland, 1960).

The shortening of the jhum cycle, in recent times, has increased the weed problem. Another reason for decline in yield of the crops under shorter cycles is the depletion of the soil of organic matter and deterioration of the soil physical conditions like water-holding capacity, cationic exchange capacity and miicrobial and faunal activities in the soil (Watters, 1971).

In north-eastern India there is a great confusion regarding the yields of crops from hill agro-ecosystems\* The Agro-economic Research Centre, Jorhat, Assam, conducted surveys on jhum yield of rice and concluded that the average yield of 800-900 kg/ha in Garo hills, Jharkhand and Arunachal Pradesh is comparable to the average yield of 1145 kg/ha/yr for the country as a whole for 1971-1972. On the other hand, the rice yield under jhum in Tripura was reported to be around 1200 kg/ha/yr (Misra, 1976). In a recent survey of the socio-economy of shifting agriculture, Aurora et al (1977) concluded that the yields of rice under jhum and dry land cultivation on terraces are not significantly different under comparable situations. A study of Burnihat (Sahu, 1978) on rice yield gave yearly outputs under valley cultivation of 3428 kg/ha, under terrace cultivation 738 kg/ha and with jhum of 853 kg/ha. According to a report of the Indian Council of Agricultural Research (Borthakur et al, 1978) the yield under jhum is very low (190 kg/ha) compared to terrace cultivation (1860 kg/ha). Unfortunately none of these studies specify the fertiliser inputs under terrace cultivation nor do they indicate the jhum pattern, the cycle of which determines the yield. None of these studies either specify whether yields from other crops

are included in the final figure.

In recent times, there has been a renewed interest in the energetic efficiency of slash and burn agriculture due to energy shortage in the present times. Data on the energetics of slash and burn agriculture is rather scarce\* Bappaport (1971) provides relatively complete information on the energy expenditure of the Tsembaga people of new Guinea highlands\* According to him, the farmers obtained an average of 16 food calories for each calorie of human energy employed during farming which may go upto 20 under more favourable conditions\* Modern agriculture is highly unstable and has many environmental repercussions; it is highly inefficient from an energy point of view as 5-10 calories of fuel energy is required to produce a single calorie of food energy (Steinhart & Steinhart, 1974). From the energy point of view, shifting agriculture seems to be the best evolved system for forested areas in tropics and sub-tropics (Coaklin, , ^?} Hye & Greenland, 1960). Bambo (1978) taking the energy data of Bappaport (1971) calculates that if the fire energy is included as an input then the output/ input ratio may drop to 0.11 which is in comparable range of efficiency of modern agriculture. Thiring the calculations

he has, however, ignored many products of the fallow which form a great source of energy to the farmers.

Forested fallows :

When the cultivated land is abandoned, its vegetation passes through several secondary successions<sup>^</sup>, communities, but rarely reaches the climatic climax before the land is again cleared. Richards (1952) made a fine survey of secondary successions in the moist evergreen forests of Africa. The first phase of the succession is dominated by weeds which are short lived and are replaced by shrubs and later on by trees. Young secondary forests tend to be even aged and are often dominated by a single species; the first dominants may form a single generation community which dies without reproducing itself and is followed by communities with other dominants. In Nigeria and much of the Congo Basin, for example, the secondary succession is often dominated by the umbrella tree (*Busanga ceeropioides*). This is a fast growing shade intolerant species with a high potassium content that dies out after about 20 years and is unable to regenerate in its own shade. Detailed studies of the early stages of succession after slash and burn agriculture have been made

## u

«\\* 7a '£& '. j\*-jLncrcL i \*tl, / \_^w south-west Ghana ty  
ihn<sub>3</sub>(1958). Clayton (1958) studied the succession on the abandoned farmland around Ibadan in western Nigeria and reported a wide range of vegetation over a relatively small area. In all these cases, the details of the successional pattern depend on the degree of cropping and exhaustion of the land, and the type of the soil.

Savannah in Africa consists of ecologically dominant stratum of more or less xeromorphic herbaceous species, of which grasses and sedges are the principal components; fire-resistant shrubs, trees and palms are sometimes also present. The density of the woody growth varies greatly according to the intensity of cultivation, the method of clearing and the severity of the annual burn (Nye & Greenland, 1960).

A variety of reproductive and growth strategies are adopted by successional species, among which stump, root and rhizome sprouts and invasion through seeds are common. Salisbury (1942), Hayashi & Humata (1968) and Raynal & Bazzaz (1975) discussed the role of high seed production in early stages of succession. The early species may be considered as most closely approaching a purely exploitive strategy, which enable them to become dominant in abandoned fields temporarily

enriched with nutrients and radiant energy (Grime, 1974j; Harper & White, 1974; Marks, 1974). The species that follow in the later phases of succession have fewer and larger seeds and a long vegetative phase (Harper & White, 1974; Bormann & Likens, 1979) and could be considered representative of the conservation strategies.

Detailed studies on succession, in temperate regions, have shown that following dominance by a few species early in the seres, there is an overall increase in species number with time. Numerous studies of the tropical successional vegetation (Kenoyer, 1929; Boss, 1954; Sarmkhan, 1964; Kellman, 1970; Law son et al, 1970) suggest that while the overall species richness is greater in tropical successional communities, the rate of increase in species richness is not basically different from that of temperate communities. Another important but least understood aspect of successional communities is the relationship between diversity, energy flow and age of the community. There seems to be considerable confusion related to diversity, productivity and stability. A general model of community structure and function has been developed (Margalef, 1958a, b, 1961, 1969; Woodwell & Smith\* 1969) with two basic approaches to evaluate stability: (i) the persistence of

certain species combinations through time and (ii) the ability of the community to resist environmental perturbations. However, a few of the generally accepted hypotheses have been experimentally tested (Odum, 1969)\*

Soil fertility :

The long term success of slash and burn agriculture depends upon the recovery and maintenance of soil fertility. If the nutrient lost or displaced during the short period of cultivation are approximately balanced by those replaced during the fallow period, the system could continue indefinitely. The maintenance of soil fertility in hot, humid and high rainfall areas is a serious problem and is more severe in situations when the cycle becomes short, due to poor recovery of soil fertility and increased intensity of weed competition. This in turn results in a reduced crop yield under short jhum cycles (Nye & Greenland, 1960; Watters, 1971).

When the forests are cleared and the debris is burnt, all the cations are released on the surface soil as ash. Heavy losses of carbon, nitrogen and sulphur occur due to volatilization during the burn (Nye & Greenland, 1960; De Las Sales & Polster, 1976). For phosphorus there

## **M**

are no obvious mechanisms of volatilization but the matter has not been closely studied. Lloyd (1971) reported high loss of total phosphorus due to burning but Allen (1964) and Vire (1974) reported no losses on account of this. Large proportion of the ash liberated after the burn is blown-off by the wind.

After the burn and during cropping period loss of organic matter from the soil due to decomposition is likely to be faster due to higher insulation and also due to rapid surface run-off. Joachim & Kandiah (1948), Ilye & Greenland (1960), Zinke et al (1978) and Jha et al (1979) reported a net loss of carbon after a year of cropping. Juo & Lai (1977) estimated a requirement of 16 ton/ha/yr of dry plant material to be added to the soil under slash and burn agriculture in order to maintain soil organic matter in the surface soil at a level comparable to soil under secondary forest, as the rate of decomposition is faster under continuous cropping. The depletion of organic matter depends upon the intensity of cropping, type of the fallow vegetation and the ratio of the cropping to the fallow period. With optimum cropping (1-2 years) and fallow period (8-10 years), the humus in the soil could be maintained at a relatively high level even after

many years of shifting agriculture (Coulter, 1950; Birch & Friend, 1956; Hye & Greenland, 1964), Similar to carbon, there is also a net loss of nitrogen after cropping compared to that before burn. Nitrification after the burn is shown to be accelerated due to high microbial activity, due to rise in pH and temperature of the surface soil (Griffith, 1949; Moore & Jaiyebo, 1963; Ahlgren & Ahlgren, 1965). The increase in nitrification after the burn has also been attributed to the removal of chemical inhibitors (Reed, 1951; Smith et al, 1968; Rice, 1974).

Nye & Greenland (1960) have reviewed a large number of fertilizer trials carried out in many parts of Africa with the main crops grown by shifting cultivators and have shown that on forest soil, whether oxysols or echrosols, responses to nitrogen have been small after fallows lasting ten years or more, but large on land more intensively cropped with only short fallows. The effect of phosphate fertilization varied with soil type, but in many places small responses have been obtained in first year of cropping and larger responses in subsequent years. Response to potash has very commonly been obtained after short fallows or on land that has been cropped for a number of years.

Deforestation has a major impact on both the amount and relative proportions of water, dissolved substances and particulate matter lost from the system\* Moreover, the total concentration of cations in the soil solution depends upon the total concentration of anions. A high level of nitrate ion due to increased 'biological activity\* (Ahlgren & Ahlgren, 1965; Wells, 1971) after burning balances a corresponding concentration of nutrient cations in the soil solution and therefore heavy losses through water occurs (Bormanufii al, 1963; Lewis Jr., 1974).

The losses of water\* nutrients and sediment are highly reduced when the land is reverted to the fallow. Under fallows in the deciduous and semi-deciduous forest zones, although there will be relatively large amounts of nitrate in the soil, leaching will be restricted both by the uptake of anions by the vegetation, and because the transpiration of a larger proportion of the rainfall will reduce through percolation. In the wetter evergreen forest zone where precipitation is high (over 200 cm), percolation is bound to occur, but leaching losses will be restricted, not only by the absorption of anions by vegetation but also by low nitrate levels in the soil, since nitrification will be limited by high acidity. Losses also depend upon the nutrient

status of the soil. Ecosystems with nutrient saturated soils would lose relatively more of their nutrients than those with nutrient depleted soils (Jordan et al, 1972)\* Per example, the northern hardwood forests (Likens et al, 1977) in which a large proportion of the nutrients is in the soil in exchangeable form would lose a relatively larger quantity out of it than tropical rain forests as in these forests most of the nutrients are tied up in the bioaass (Odua, 1971; Jordan et al, 1972) and mineral soil has very low nutrient content (Went & Stark, 1968)•

The depletion of various nutrients in soil continues in the early successional stages. The transfer of nutrients from sub-soil to top-soil probably does not begin until after the first year or two of fallow; during this initial period the top-soil is further depleted by leaching and by the uptake of nutrients by the regenerating vegetation, which has few active roots in the sub-soil at this stage\* Popenoe (1959) showed under regenerating forest fallow in Guatemala that there was an initial depletion of the surface soil, after which the level of cations rose in the top 3 cm, and fell in the layers below, as the vegetation developed. Valentine (1976) also reported rapid depletion of soil with exchangeable cations upto 7 years of the regeneration burn in

## M

south-western Australia. Zinke et al\_ (1978) also made similar observations with the 'Lua\* forest fallow system in Thailand.

mnwa.Ra<sub>f</sub> Productivity and Litterfall :

A sharp increase in the aboveground biomass occurs during secondary succession. According to Lugo (1973) maximum biomass value for tropical forests is approached in about 30 years at a level of 250 m.ton/ha where as in the temperate forest in northern hardwoods of USA, after clear-cutting the living biomass rises to a peak of 490 m.ton/ha in about 170 years only (Bormann & likens, 1979). While according to Margalef (1968), Odum (1969), Whittaker & Woodwell (1972) a steady-state for biomass immediately follows the attainment of the peak during succession, according to Bormann & Likens (1979) this is reached only after a transition period of more than 100 years. In any case, a steady-state for biomass is reached over a shorter time period in the tropics than in the temperate forests. The rate of accumulation of biomass is faster in the early stages of succession but may decline in the subsequent years. Snedaker (1970) reported maximum rate of increase of biomass of 19.23 m.ton/ha/yr upto 7 years in lowland forests in Izabel, Guetamala. Bartholomew et al

(1953) reported a maximum rate of 26.6 m.ton/ha/yr in a new forest of Musanga eecropioides upto a period of 5-8 years. However, the rate of biomass accumulation during succession also depends upon the type of vegetation established and other environmental conditions. Tropical forests as a whole, with a mean annual net primary productivity of 21.6 m.ton/ha, exceeds temperate forests, averaging 13.0 m.ton/ha and boreal forests averaging 8.0 m.ton/ha (quoted by Lugo, 1973). Jordan (1971) reported values of 5.4 m.ton/ha/yr for a 3 year old successional forest and 10.3 m.ton/ha/yr for old rain forests in Puerto Rico. In an oak-pine forest in New York, net primary productivity (Holt & Woodwell, quoted by Whittaker, 1975) increased to a fairly stable level in the meadow stage of succession and increased more steeply through the shrub and the young tree stage to 12 m.ton/ha/yr in the oak-pine forest of 44-45 years age. Mellinger & McNaughton (1975) showed a contrasting trend where over a 30 year period during succession in old fields in central New York, there was a decrease in average net productivity.

During development of vegetation, a part of the nutrient is stored in the vegetation and part is returned to the surrace soil by rain wash irom leaves and twigs, by litter and twig fall, and in the form of dead roots and

and root exudates. The soil humus is increased during fallow period, chiefly as a result of litter. Relatively high value of litter production is found in the secondary successional communities compared to the mature ones (Mitchell, cited by Bray & Gorham, 1964; Ewel, 1976). This is because of the fast rate of development of the community in the early successional stages.

Nutrient cycling :

The information on the chemical content of tropical vegetation has been summarized by Sodin & Bazilevich (1967); studies of the dynamics of mineral cycling include those of Laudelot & Meyer (1954), Greenland & Kowal (1960), Nye (1961), Dommergues (1963), Bozanov & Hozanova (1964), Odum & Pigeon (1970), Odum (1970), Stark (1970) and Golley et al (1975). While the information is quite limited, certain patterns are nevertheless suggested by these studies: (i), the uptake and return of nutrients may be greater per year in tropical, forests than in other type of vegetation (ii), a larger proportion of the entire chemical inventory of the system is held in the vegetation, (iii), in tropical forests the percentage of the vegetation in green parts, the proportion lost per year as litter, and the rate of decomposition of the litter are greater



## 2k

than in temperate forests, (iv), the rate of uptake is strongly influenced by the rate of evapotranspiration.

The average concentration of elements in the vegetation of tropics is shown to be higher in the second-growth than in the mature forests (Golley et al, 1975) because of their high requirement of nutrients. Potassium is more abundant of all the elements in the early successional forest but calcium tends to be more in mature forests (Bartholomew et al, 1953; Golley et al, 1975).

Mineral cycling probably varies with the nutrient supply to the system, with the time available for the system to develop on the site and also the environmental conditions\* the accumulation of nutrients and their release through litterfall increases with the age of the fallow and becomes stabilized in mature forests. The type of soil may also play a great role, as for e.g., the soil in certain Amazonian forests (Stark, 1971 a,b; Klinge & Hodrigues, 1968 a,b) are podsols which contain low quantities of nutrients and have low exchange capacity. As a consequence, concentration of nutrients in plants are much higher than in the soil and the elements released from the litter are rapidly taken up by the plants; the litter is also low in nutrients than in other forests (Klinge & Bedrigues, 1968b).

The Amazon case has led Stark (1971a) to propose a direct nutrient cycling hypothesis which states that on poor Amazon soils nutrients are transported from dead organic matter by mycorrhizal fungi directly to living plant roots without appearing in the soil solution.

Misra (1972) presents data on tropical dry deciduous forests near Varanasi, India. The annual rainfall where this forest grows in India is 70 to 80 cm and distributed in a short period. The turnover of the nutrients in the biomass is rapid (p, 44 years; Oa, 20 years; and H, 70 years). Apparently in this environment availability of water is the major limiting factor to forest production and because of the environmental conditions the amount of nutrients that can be incorporated into the biomass is relatively small and these are conserved by rapid cycling between the biomass and substrate.

A complete destruction of forests under slash and burn agriculture disrupts the mineral cycling, because the system loses its ability to hold the nutrients. The development of the regulatory functions depend upon the reestablishment of biotic compartment which in turn regulates the uptake of nutrients and water, nutrient storage, decomposition, nitrification, mineralization and erosion.

Rapid recovery of these ecosystem characteristics are promoted by temperature, moisture, and nutrient conditions favourable to plant growth (Likens et al, 1978).

The present study attempts a detailed analysis of agro-ecosystem structure and function with respect to cropping and yield pattern and also the energetic efficiency of the different slash and burn agriculture cycles (Jhum cycles) at a lower elevation of the Khasi hills of Meghalaya at Burnihat (located at 26°N and 91.5°E) 30 km. north of Shillong. 4-10 and 5 year Jhum cycles were compared between themselves as well as with terrace cultivation and valley cultivation of wetland rice.

Immediately prior to burning the slash and through the first year of cropping, the nutrient availability in the soil, the pattern of loss of water, sediment and nutrients through run-off/leaching were also studied. These studies were continued through various stages of development of fallows.

(3) The development of secondary communities was analysed in detail with respect to species composition, biomass accumulation, litterfall and productivity. On the basis of the above studies, on the basis of detailed nutrient analysis of the different compartments of the developing ecosystem, the nutrient cycling pattern was worked out.

CHAPTER 1

CROPPING AND YIELDS IN AGRICULTURAL  
SYSTEMS OF THE NORTH-EASTERN HILL  
REGION OF INDIA.

CROPPING AND YIELDS IN AGRICULTURAL SYSTEMS OF THE  
NORTH-EASTERN HILL REGION OF INDIA

INTRODUCTION

Lower elevations of the north-eastern hill region of India are characterised by mixed sub-tropical humid forest types and traditionally have two types of agricultural systems, namely (i) slash and burn agriculture, locally known as jhum, and (ii) rice cultivation in valleys and flat lands between the mountainous slopes. In recent times, there has been an attempt by governmental agencies to discourage shifting agriculture and to provide terraced land for cultivation along the hill slopes. This form of agriculture necessitates heavy inputs of fertilizers to correct the poor nutrient status of the soils which are of lateritic origin.

The present study site at Burnihat in the Khasi hills and about 90 km north of Shillong is located at 26°N and 91.50°E. The soil is red, sandy loam and of laterite origin. The pH ranges from 5 to 7. Angle of

the slopes generally range from 20° to 40°. The rainy season extends from May to September during which 90% of the annual average rainfall of 220 Cm occurs. Maximum temperature and humidity is also attained at the time. There is a mild winter during December - February and temperatures begin to rise during March and April; this is largely a dry period. The three different agricultural systems at Burnihat at an elevation of 100 m. in Meghalaya are typical of the pattern at lower elevations in the north-eastern region. The tribal population engaged in this form of agriculture are the 'ffaros\*.

There is some confusion regarding the yield of crops from hill agro-ecosystems in the north-eastern India.

-ECo

The Agronomic Research Centre, Jorhat, Assam, conducted surveys on Jhum yield of rice and concluded that the average yield of 800-900 kg/ha in ffaro hills, Mizoram and Arunaohal Pradesh is comparable to the average yield of 1145 kh/ha/yr for the country as a whole for 1971-1972. On the other hand, the rice yield under jhum in Tripura

'was reported to be around 1200 kg/ha/yr (Misra, 1976). In a recent study of the socio-economy of shifting agriculture, Aurora et al, (1977) concluded that the yields of rice under jhum and dry land cultivation on terraces are not significantly different under comparable situations. A study of Burnihat (Sahu, 1978) on rice yield gave yearly outputs under valley cultivation of 3428 kg/ha, under terrace cultivation 738 kg/ha and with jhum of 853 kg/ha. According to a report of the Indian Council of Agricultural Research (Borthakur et al, 1978) the yield under jhum is very low (190 kg/ha) compared to terrace cultivation (1860 kg/ha).

Unfortunately none of these studies specify the fertilizer inputs under terrace cultivation nor do they indicate the jhum pattern, the cycle of which determines the yield. None of the above studies specify whether yields from other crops are included in the final figures. The present studies have therefore attempted an objective comparison of the various systems.

#### METHODS OF STUDY

For studies of the jhum system, fields that had 30, 10 and 5 year cycles were selected. Mixed cropping

was done only for one cropping season after slash and burn in all three fields. The data presented for different jhum cycles refer to mixed<sub>A</sub> in the first season after sowing. The differences in the composition of the crop mixture under different jhum cycles are due to differences in the mixtures' sown. Thus, the farmer tends to emphasize cereal and grain crops under long jhum cycles whereas they emphasize leaf and vegetable crops or tuber and rhizomatous crops under shorter jhum cycles. Fields with valley and terrace cultivation were also selected in the same area. When selecting the fields, care was taken to ensure that they were subject to minimal disturbance from wild animals like monkeys, wild pigs and elephants which are common in the area.

Since weeding was done in all the fields, the weeds could not be considered for vegetational analysis, only the crop mixtures raised were analysed soon after a weeding but when majority of the crops had attained maximum vegetative growth in July but just before the harvest of Zea mays and Setaria italica. Thus, the vegetational analysis is based on the individuals of the different crops<sub>A</sub> in the jhum fields were analysed for frequency, density and cover using 1 m quadrats. The importance

value index (I V I) values were calculated based on relative frequency, relative density and relative basal area of the crop species and are based on 20 quadrats per field (Misra, 1968; Kershaw, 1973). Plant spread is a measure of the average ferial spread of the shoot of a given species and \$ cover is expressed on the basis

A,

of the total Serial spread of the individuals of that species and is a measure of plant abundance (Kershaw, 1973).

For all crops, the biomass and economic yield per plant were determined in the field from the average of 15 plants per plot. Tho biomass and economic yield per plant wore dotormined in the field\*-from thp average of 15 plants per plot-» The biomass and economic yield per hectare in all cases watoe. calculated on the basis of the yield from the entire field. Labour inputs in man hours for all operations were calculated. The total economic yield was converted into rupees on the basis of prevailing market prices. Labour charges for male and female *ffafa* hours were calculated on the basis of prevailing daily rates of Rs.7/- and Rs.5/- respectively.

#### DESCRIPTION OF AGRICULTURAL SYSTEMS

##### Jhum agro-ecosystem:

Slash and burn agriculture locally known as 'Jhum'

is extensively practised by the tribal population of the hill areas in the north-eastern region of India. This practice consists of cutting down the forest at various stages of development on the hill slope, allowing the slash to dry for a few months and burning it before stopping for one or two years. The fallow period before the land is again cultivated is often short ranging upto four or five years but in the traditional type when the population pressure was not so great the cycle may be as long as 20-30 years. (Ramakrishnan et al 1980; Bamakrishnan & Tgky, 1978).

This practice is also prevalent at lower elevations of Meghalaya, as for example at Bu'rnihat, similar to that in other parts of the north-eastern hill region with respect to : (i) topography with cultivation being done on slopes of 20-40<sup>o</sup>, (ii) soil type which is a red sandy loam of lateritic origin (iii) climate with high rainfall of a monsoonic nature followed by a dry winter and a brief warm summer supporting a mixed subtropical humid forest. (iv) Jhum cycle which is usually a short one of four to five years but very rarely may be of longer duration of 10-30 years. The average size of a jhum plot varies from 1.0 to 2.5 hectares. The average family consists of two adults and

three to four children.

During the winter months (December-January) the undergrowth is slashed and small trees and bamboo are felled. The boles of the larger trees are not felled; only the lower branches are cut down. Short stumps of the trees are left intact and underground organs of different species are not disturbed. This is the most laborious task of all the agricultural operations and is sometimes completed by two or three families working together. Only men take part in this operation.

Before the onset of monsoon, towards the end of March or beginning of April, the dried debris is burnt in situ. Before burning, a fire line is cleared around the field. Burning is often repeated to destroy any unburnt material which is first collected in heaps. A bamboo hut is built for temporary living and the presence of the family protects the field from wild animals.

The seed mixtures used for different jhum cycles may vary considerably. Cereals constitute the major component of the seed mixtures under long jhum cycles whereas perennials and tuberous crops are important under short jhum cycles. Some 8 to 13 crops species are sown together in the same field.

Seeds of pulses, cucurbits, vegetables and cereals like Setaria italioa are mixed with dry soil from the sites, in order to ensure their uniform distribution and broadcast immediately after the first burning. All unburnt debris is heaped and burnt for a second time. Maize seeds are dibbled at regular intervals amongst other crops. Similarly, rice is sown into the crop mixture by dibbling using a long stick after the first rainfall, during mid April. Semi-perennial and perennial crops such as ginger, colocasia, tapioca, banana and castor are sown intermittently, and at random, throughout the growing season. The leaves of Bleinua communis are used for rearing young silkworm caterpillars. The leaves of some dicot tree species also may be used for this purpose but for feeding older caterpillars. Fallows, after clearing and burning, are utilised only for one year except when a garden of banana, pineapple or orange is maintained after the first year of mixed cropping.

Weeds pose a great problem with the starting of the rainy season in April and May. They comprise root sprouts, rhizome sprouts and stump sprouts, tree seedings, grasses and herbs. Under the long jhum cycle the problem is not as severe as those under short jhum cycles where many weeds particularly Imperata cylindrica which keep sprouting

from underground rhizomes and are difficult to eradicate (Bamakrishnan & Taky, unpublished). Though Eupatorium odoratum is also an important weed, frequent slashing keeps it under control during the cropping season. Hand hoeing is usually done twice (3-4 times under short cycles) during the cropping season mainly by women.

Valley land agro-ecosystem:

Unlike jhum cultivation, valley land agriculture is a monoculture of rice. Further, this is a sedentary and settled form of agriculture. Two crops are taken annually from the same land, because the land is comparatively fertile, due to nutrient wash *otiL±* from the hill slopes, and does not need added fertilizer. Field preparation for the first crop is done in February-March, seedlings are raised in nursery beds in the month of March, transplanted in the beginning of April, and crop harvesting is completed by end of July or early August. Immediately after the first harvest the fields are again prepared and seedlings already raised in nursdry beds are transplanted with harvesting completed by October-November. Subsequently the land is fallowed

between November and March. The operations of weeding, transplanting, harvesting, threshing, etc. are all done manually by both male and female members of the family. Preparation of field is done either manually or by using bullocks controlled by male members only.

Terrace land agro-ecosystem:

In order to discourage farmers from jhum cultivation, bench-terraced land prepared by the local Soil Conservation Department was provided free to local farmers. However, because only about 200 hectares of land was terraced, this form of farming is uncommon. Terraced farming is similar to jhum cultivation in the use of mixed cropping. As many as 14 crops may be raised together and harvested sequentially. A major difference from the jhum system concerns the heavy input of fertilizers, initially provided free by the local Soil Conservation Department but with the cost now borne by the farmers.

#### RESULTS

Table 1.1 shows the mixtures and relative importance of crops sown under 30, 10 and 5 year cycles. In the sites that were studied, cropping was done for one year only after which the land was left a fallow. During the cropping year, under the long jhum cycles (30 year)

Table 1.1

Phytosociology of crops under 30, 10 and 5 year jhum cycles

Crop species	Frequency (%)			Density (plants/m <sup>2</sup> )			Basal area (m <sup>2</sup> )			(iwV.J <sup>2</sup> )		
	30 yr	10 yr	5 yr	30 yr	10 yr	5 yr	30 yr	10 yr	5 yr	30 yr	10 yr	5 yr
Oryza sativa	100	100	100	8.60	12.20	1.50	52.92	23.90	3.22	163.62	175.49	114.20
Sesamum indicum	80	35	5	1.10	0.50	0.05	1.45	1.41	0.12	28.27	19.93	4.54
Zea mays	80	25	15	1.80	1.50	0.15	4.78	1.75	0.15	38.17	23.35	13.22
Setaria italica	90	30	15	2.10	0.50	0.20	0.85	0.18	0.07	36.85	14.93	14.79
Phaseolus mungo	5	-		0.10			0.01			1.86		
Ricinus communis	20	—		0.20			1.90			8.97		
Hibiscus sabdarif <sup>a</sup>	10	20	20	0.10	0.20	0.20	0.53	0.75	0.80	3.84	10.70	19.66
Hibiscus esculentus	-	10			0.10			0.14			4.75	
Capsicum frutescens	-	5			0.05			0.02			2.24	
Lagenaria leucantha	10	5		0.15	0.20		0.21	0.18		3.69	3.59	
Cucurbita maxima	5			0.05			0.08			1.63		
Cucumis sativa	10			0.15			0.21			3.69		
Momordica charantia	-	10			0.15	-		0.01			4.73	-
Musa sapientum	-	10	30		<b>0.18</b>	0.39		f. <sup>A</sup> B	20.34		21.57	95.44
Tanacetum officinale		10	10	0.05	0.10	0.10	0.16	0.74	0.74	1.75	6.27	11.00
Polocasia antipodum	5	5	15	0.15	0.20	0.20	1.97	3.61	3.50	5.21	12.28	26.95
Zingiber officinale	5			0.05			0.10			1.66		

cereals constitute the major component of the crops sown usually with an admixture of pulses and vegetables. Under the five year jhum cycle, sesamum, leafy vegetables, semi-perennial and perennial crops predominate. In the 10 year cycle, cereals are sparsely sown with greater emphasis on semi-perennial and perennial crops. Under all the «jhum cycles, rice has the highest importance value index (I V I) followed under a 30 year cycle, by maize, Setaria italica and Sesamum indicum. The next important crops are maize, banana and sesamum under a 10 year cycle, and under a 5 year cycle are banana, Hibiscus sabdarif<sup>f</sup>a and colocasia. Although rice has the greatest 17 1 value under all the three situations, its importance relative to basal area/m was much reduced under 10 and 5 year cycles compared to that under a 30 year cycle. The number of crops sown was reduced with the shortening of the jhum cycle from 13 under a 30 year cycle to 8 under a 5 year cycle.

A multistoreyed crop canopy develops, with perennial crops such as cassava, banana and castor occupying the top layer, cereals constituting the middle layer and cucurbits and legumes forming the lower most stratum. The average plant spread which is one of the indices for plant vigour and is also indicative of growth habit reaches a maximum

for perennials which are widely scattered in the field. The average plant spread of some of the leaf and fruit crops like Hibiscus sabdarifa improved under short 3hum cycle. However, the average plant spread for all the cereals was maximum under a 30 year cycle and was significantly reduced with the shortening of the jhum cycle. Rice and maize showed high ground cover values under 30 and 10 year cycles with Musa sapientum and Hibiscus sabdarifa having high percent cover under a 5 year cycle. Setaria italica and Zea mays are the first crops harvested in mid July. After harvesting the grain, the remainder of the plants are slashed. Rice is harvested during September. Harvest from Cucurbits starts early July and continues into September. The root and rhizomatous crops such as Cassava, ginger and colocasia are harvested during October-November. Castor and banana are retained for a longer time and are harvested during January-February (Table 1.2).

The total biomass (root and shoot) obtained from grain and seed yielding crops under a 30 year jhum cycle was 2.5 and 20.5 times more than that under 10 and 5 year respectively. The total biomass from leafy and fruit vegetable crops was maximum under a 5 year jhum cycle and it was 2.8 and 24.5 times more than under 10 and

Table 1.2

Crop vigour (with S.E. values) and harvesting pattern under 30, 10 and 5 year jhua cycles.

Crop Species	Average plant height (Cm)			Average plant spread (m)			Ground cover (%)			Time of harvest
	30 yr	10 yr	5 yr	30 yr	10 yr	5 yr	30 yr	10 yr	5 yr	
Oryza sativa	130 +3.9	101 +2.5	95 +3.5	0.20 +0.006	0.07 +0.002	0.05 +0.002	35.8	23.3	3.7	Early September
Sesamum indicum	187 +4.5	189 +3.5	193 +2.8	0.24 +0.005	1.45 +0.014	1.32 +0.012	5.5	20.7	3.2	Early October
Zea mays	214 +4.6	221 +3.9	216 +3.8	0.56 +0.013	0.50 +0.010	0.23 +0.006	21.2	21.3	1.6	Mid July
Setaria italica	183 +2.5	170 +3.0	165 +2.8	0.11 +0.004	0.09 +0.002	0.06 +0.002	4.8	1.2	0.5	Mid July
Phaseolus mungo				6.13 +0.007			0.2			Early October
Ricinus communis	292 +5.8			5.07 +0.320			21.3			Jan - Feb
Hibiscus sabdariffa	165 +3.8	121 +2.8	132 +2.9	0.73 +0.017	1.67 +0.034	1.82 +0.040	1.5	9.5	18.0	Early December
Hibiscus esculentus	-	112 +1.5			0.40 +0.009			1.1		Early November
Capsicum frutescens	-	76 +1.8			0.11 +0.010			0.1		Early October
Leguminaria leucantha	-			0.75 +0.021	0.88 +0.027		2.3	5.0		Early September
Cucurbita maxima	-			0.55 +0.024			0.5'			Early November
Cucumis sativa				0.50 +0.019			1.5			Early September
Momordica charantia	-				0.25 +0.009			1.0		Early September
Musa sapientum		204 +5.8	285 +4.9		4.58 +0.194	4.63 +0.198		13.0	68.7	Jan - Feb
Manihot esculenta	203 +5.0	249 +5.5	243 +3.5	1.44 +0.018	1.19 +0.015	0.83 +0.010	1.5	3.3	4.0	Early November
Colocasia antiochorum	115 +1.5	112 +1.3	106 +1.6	1.08 +0.035	0.01 +0.001	0.01 +0.001	3.4	0.1	0.1	Early November
Zingiber officinalis	50 +1.8			0.06 +0.002			0.1			Early October

30 year cycles respectively. The biomass obtained from tuberous and rhizomatous crops under the 10 year cycle was almost twice the output of the other two cycles. The dry weight yield per plant for grain and seed yielding crops was best under a 30 year cycle and it was much reduced in 10 and 5 year cycles. The yield per plant of *Hibiscus sabdarif*<sup>f</sup> was higher in a 5 year jhum cycle, whereas *Musa eapientum* did best under a 5 year cycle. Of the tuber and rhizome crops, *Manihot esculenta* gave higher yield per plant under a 10 year cycle whereas *Golacacia anticuprum* did well under a 30 year cycle (Table 1.3). Maximum economic yield per hectare for rice, maize and *Setaria italica* was obtained under 30 year cycle, the reduction in the economic yield of grain and seed yielding crops was 48\$ and 98\$ under 10 and 5 year cycles respectively. However, the total economic yield of leafy and fruit vegetables, and tuberous and rhizomatous crops was higher in 5 and 10 year jhum cycles than under a 30 year cycle (Table 1.4). -

Similarly the economic yield per plant for grain crops was much reduced in 10 and 5 year jhum cycles in comparison with the 30 year cycle. The seed yield per plant in sesamum was found to be higher under 10 and 5 year

Table 1.3

Mean plant weight and biomass of crops (with S.E. value) under 30, 10 and 5 year jhum eyeles.

Crop specxes	Dry wt.yield/plant (gf)											
	30 yr		10 yr		5 yr		30 yr		10 yr		5 yr	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Oryza sativa	14.1+1.2	88.5+5.6	2.2+0.2	20.0+2.5	3.5+1.5	25.4+3.0	1213	7614	268	2440	53	381
Sesamum indicum	14.8+2.0	138.0+8.8	20.5+3.0	327.3+15.0	15.0+3.0	300.8+12.5	163	1519	103	1637	8	150
Zea mays	13.5+0.9	185.6+11.6	7.5+0.9	108.1+8.8	5.8+0.5	90.8+8.0	243	3342	113	1623	9	136
Setaria italica	3.3+0.4	34.1+2.8	2.5+0.3	24.2+1.8	2.5+0.2	20.5+1.8	69	716	13	121	5	41
Phaseolus mungo	0.5+0.1	38.0+3.1	-	-	-	-	1	38	-	-	-	-
Ricinus communis	65.5+4.3	498.1+24.2	-	-	-	-	131	996	-	-	-	-
							(1820)	(14226)	(497)	(5821)	(75)	(708)
Hibiscus sabdarifa	23.0+1.7	300.9+20.5	36.0+2.8	588.5+30.0	45.0+3.2	615.8+25.2	3	301	72	1177	90	1232
Hibiscus esculentus			7.5+0.8	88.5+4.6	-	-	-	-	8	89	-	-
Capsicum frutescens			3.4+0.4	7.6+0.9			-	-	2	4		
Lagenaria leucantha	2.0+0.2	126.2+8.6	0.9+0.2	65.6+5.2	-	-	3	189	2	131		
Sucurbita maxima	5.4+0.5	175.2±10.5	-	-			3	88	-	-		
Cucumis sativa	0.4+0.1	32.4+3.0	-	-			1	48	-	-		
Momordica charantia *			1.0+0.2	11.0+2.6	-	-	-	-	2	17	-	-
Musa sapientum			825.0+67.8	3350.0	1108.4	3825.0			825	3350	3325	11475
				+256.8	+2.4	+260.2	(30)	(627.)	(911)	(4768)	(3415)	(12707)
Manihot esculenta	678.0+32.5	626.0	1351.7	960.1	690.0+	620.0+22.8	339	313	1352	960	690	620
		+25.5	+58.5	+48.5	3318"							
Oolocasia anticuorum	222.6+13.8	28.4	186.5	13.4	110.3	12.5+0.8	334	43	373	27	221	25
	~	+1.4	+10.3	+0.8	+6.5"							
Zingiber officinalis	19.0+0.7	8.0					10	4				
		+0.4					(683)	(360)	(1725)	(987)	(911)	(645.0)

Values in parentheses are totals of each category,

Table 1.4

Comparison of mean economic yield (with S.E.values) of crops under 30, 10 and 5 year jhum cycles.

	Yield/plant			Total yield (kg/ha/yr)			Moisture content
	30 yr	10 yr	5 yr	30 yr	10 yr	5 yr	
Dryza sativa	13.5+0.6	3.1+0.3	4.4+0.3	1161.0	378.2	66.0	19.5
Sesamum indicum	40.6+2.4	108.1+3.7	50.0+2.6	446.0	540.5	25.0	7.3
Zea mays	42.8+2.8	26.5+1.5	20.0+1.2	770.0	397.0	30.0	15.0
Setaria italica	9.2+0.3	4.6+0.2	4.2+0.1	193.2	23.0	8.5	17.0
Phaseolus mungo	10.0+0.4	-	-	10.0	-	-	25.0
Ricinus communis	2.5+0.2	-	-	5.0	-	-	12.0
				(255.2)	(1338.7)	(129.5)	
Hibiscus sabdariffa	34.3+1.9	69.7+2.8	48.0+2.3	44.3	139.4	96.0	75.0
Hibiscus esculentus	-	50.0+2.7	-	-	50.0	-	65.0
Capsicum frutescens	-	1.8+0.2	-	-	0.9	-	80.9
Lagenaria leucantha	93.3+4.0	40.2+2.6	-	140.0	80.5	-	93.0
Cucurbita maxima	124.6+4.6	-	-	62.3	-	-	90.5
Cucumis sativa	10.4+0.4	-	-	15.7	-	-	91.9
Momordica charantia	-	3.0+0.2	-	-	4.5	-	81.5
Musa sapientum	-	105.0+6.5	162.6+7.8	-	105.0	488.0	77.5
				(262.3)	(380.3)	(584.0)	
Manihot esculenta	678.0+32.5	1351.7+58.5	690+33.8	339.0	1351.7	690.0	59.1
Colocasia antiprura	73.1+3.1	147.0+5.8	90.0+3.4	259.6	294.0	180.0	79.0
Zingiber officinale	19.0+0.7	-	-	9.5	-	-	51.9
				(608.1)*	(1645.7)	(870.0)	
Cocoon (with pupae)				4.2			2.0
Cocoon (without pupae)				0.2			89.5

Values in parentheses are totals of each category.

jhum cycles than under a 30 year cycle (Table 1.4).

In valley land agriculture rice yielded 3710 kg/ha/year (1880 kg/ha for the first crop and 1830 kg/ha for the second crop). In the terrace system, the yields

**(JI\*9**

of rice, maize and vegetable crops were generally good. Amongst the tuberous crops, Manihot esculenta gave high yield (Table 1.5).

Table 1.6 gives the calculated labour costs of the different types of agriculture. In the case of terrace cultivation fertilizer cost comes to Rs.800.00 per ha, but the labour cost for terracing has not been included in Table 6. The input in terms of rupees for cultivation under a 30 year jhum cycle is very close to that under terrace cultivation and for raising a single crop under valley cultivation. The input for cultivation under a 5 year jhum cycle is the least, one third of that under a 30 year cycle; the 10 year cycle is intermediate between the other two. It may be noted that maximum input goes into raising two crops under valley cultivation and hence the output/input ratio is lowest for valley cultivation.

#### DISCUSSION

Mixed cropping is very common in shifting agriculture in different parts of the world (Schlippe, 1956;

Table 1^5

Economic yield of crops under terrace ctaltivationt.

	Crop species	Total yield kg/Wyr	<	^	^
	<b>dryza sativa</b>	<b>955;0</b>			
∞	<b>Sesasan iridic tm</b>	<b>20^5</b>			
	<b>Zea nays</b>	<b>144.0</b>			
	<b>rkaseolus mango</b>	<b>?io</b>			
	<b>Ricinua comaunis</b>	<b>&amp;i0</b>			
	<b>Hibiscus sabdarifa</b>	<b>9&amp;Z5</b>			
	<b>Cucurbita aaxlaa<sup>A</sup></b>	<b>95.0</b>			
	<b>MoMordica charantia</b>	<b>9*5</b>			
<b>St</b>	<b>Fkxaeolus vulgaris</b>	<b>15.0</b>			
	<b>Hose sapLentua</b>	<b>180J90</b>			
	<b>Manikot esculenta</b>	<b>13081^</b>			
•8 «	<b>Cplocasia antic^ru*</b>	<b>9€\$0</b>			
	<b>Zingiber officinalis</b>	<b>22.0</b>			
	<b>Curcuna long a</b>	<b>16\$3</b>			
	<b>Cocoon (silk)</b>	<b>4.0</b>			
<b>38</b>	<b>Fopae (without cocoon)</b>	<b>0%</b>			
∞ >					

**Table 1.6**

**Monetary input-output (RfSJ/ha/yr) into jhum, terrace and valley agriculture systems.**

	<i>JZQJZZ</i>	<u>Jhum</u>		Terrace	<u>I crop</u>	<u>Valley.</u>	<u>I &amp; II crop</u>
		10 yr	5 yr			II crop	
<b>Input</b>	<b>616</b>	<b>1830</b>	<b>896</b>	2542 (4544)	<b>2602</b>	<b>2241</b>	4843
<b>Output</b>	<b>5586</b>	<b>3354</b>	<b>1690</b>	3658	<b>2820</b>	<b>2745</b>	5565
<b>Net gain/ loss</b>	<b>2970</b>	<b>1524</b>	<b>794</b>	<b>1116</b> <b>(-886)</b>	<b>218</b>	<b>504</b>	<b>722</b>
<b>Output/ Input</b>	<b>2.13</b>	<b>1.83</b>	<b>1.88</b>	<b>1.43</b> <b>(1.07)</b>	<b>1.08</b>	<b>1.22</b>	<b>1.14</b>

**Values in parentheses indicate values for the first year of terrace cultivation<sup>^</sup>**

Conklin, 1957; Nye & Greenland, 1960). Mix crop cultivation is accompanied by successive harvesting of the different crops. The crops may be planted simultaneously as in the present case, and in the Philippine where as many as 40 or 50 crops are planted at the same time (Conklin, 1957), or root crops may be planted after the harvest of cereals as in the forest zones of Ghana (Nye & Greenland, 1960).

In mixed cropping under Jhum, several crop species with diverse growth habits, root system and mineral nutrient requirements enable optimum use of the available space and resources. An extraordinarily large leaf area index is possible because of the storeyed disposition of foliage. The multistoreyed canopy also protects the land from excessive soil **eraction** and leaching. Multiple cropping provides an 'insurance policy\*' to the cultivators because some crops are likely to give a good return even if there is partial or complete failure of other crops. ^Further, the farmer manages to get all his diverse requirements in cereals, vegetables and tuber crops from the same site. The juxtapositioning of so many crops tends to minimize the incidence of pests and disease. The pre-

planting burning also ensures control over Jgts and other harmful insect pests.

The successive harvesting of crops also confers some advantages. Thus after harvesting maize and Setaria italica, rice gets more space at the peak of its growth period. Successive harvests of cereals create additional space for the remaining semi-perennial and perennial crops which also get organic matter and nutrients from the decay of plant debris. This practice also ensures a more even distribution of labour.

In the past, a 20 to 30 year jhum cycle was usual in the entire north-eastern hill regions of India. This ensured the development of a good forest cover and adequate recovery of the soil -with respect to nutrient status (Ramakrishnan & Toky, 1978; Ramakrishnan et, al, 1980).

Now, because of higher population densities the cycle is often as short as 4-5 years. The decline in grain and seed

o

yield that has fallowed may partly be because of aggressive weeds like Eupatorium odoratum and Imnpera^a cvlindrica and partly from insufficient recovery of the soil's nutrient status. A fallow period lasting a minimum of 10 years is needed for natural elimination of weeds like Eupatorium

odoratum and Imperata cylindrica. The weed problem related to yield under different jhum cycles is currently receiving o^jSr attention.

Weeds are major cause of declining yield under slash and burn agriculture in many parts of the world and include Eupatorium odoratum in Thailand (Zinke et al., 1978) and Imperata cylindrica in Sarawak (Freeman, 1955).

Cutting et al (1969) reported that the yield of maize in 01/ Ny^saland was 4284 kg/ha when weeded four weeks after germination but attained only 3217 kg/ha when weeded six weeks after germination.

Five years is not sufficient time to restore the chemical fertility and improve the physical conditions of the soil. • Bamakrishnan & Toky (unpublished) have shown that the first 10-15 years of fallow growth results in rapid depletion of nutrients by developing vegetation; the release of nutrients held in the living biomass starts only in after about 15 years of fallow period. High rainfall and steep cultivated slopes caii.se much loss of nutrients during cropping particularly with the absence of crop cover at sowing and during crop establishment and after harvest (Toky & Ramakrishnan, unpublished). According to Watters (1971) short fallow systems have led to declining

harvests in three main staple crops in Yenezuala; maize decreased from 803 kg/ha to 640 kg/ha and Yucca and be\*n productions fell 60# and 100\$ respectively. On the other hand, the high yields of Sesamum, tapioca, banana and leafy vegetables under a short ahum cycle may arise because of rapid initial growth giving quick cover which also shades out weeds. Further, deep and extensively branched root systems ensure efficient use of available nutrients.

Settled valley cultivation is tenable in the north-eastern hill region, both from economic and ecological viewpoints. It depends upon natural inflow of nutrients into the valleys from the adjoining hills. Even so the rice yield per crop is not more than 1880 kg/ha and the system does not include all the other crops grown under the j&um system. The economic viability of 30 year jhum cycle becomes more apparent when one considers the earning capacity of the farmer under these two systems. Two crops of rice under valley cultivation are equivalent to one mixed cropping under a 30 year jhum cycle. Labour input into valley cultivation is significantly higher than under jhum cultivation because of the care and effort that goes

into ploughing and other preparations of the land and the need for frequent weeding; all these operations are done twice a year to raise the two crops. The main advantage of valley cultivation is the raising of crops, consistent in yield year after year from the same site.

Under terrace cultivation the yield is very low in relation to inputs of labour and fertilizer. The monetary output is comparable to that from a 10 year jhum cycle. However, the first year of terrace cultivation gave an output/input ratio of less than one because of the heavy labour needed for terracing the site. In subsequent years the ratio is still lower than the ratio for jhum cultivation but higher than that for valley cultivation. However, the valley cultivation ratio includes family labour for land preparation and weeding. The fertilizer input to terraced cultivation is as much as 60 kg. of N, 30 kg of  $P_2O_5$  and 30 kg of  $K_2O$  per year.

Thus the results presented here and those as yet unpublished indicate that the long jhum cycle are viable but the short cycles cannot be sustained both ecologically and also economically. Terrace cultivation as advocated by the agricultural Scientists also cannot

be sustained economically because of heavy inputs and also on ecologic considerations. Our hydrological studies show that even if run-off losses are checked due to terracing, infiltration losses may contribute to as much as 50% of the water lost from the system (Iyengar et al. 1980). Valley cultivation is sustainable on both ecologic and economic considerations.

#### SUMMARY

Shifting agriculture locally known as jhum is the predominant form of agriculture used by the local tribe along with some valley rice cultivation and terrace cultivation. The structure and some functional aspects of these three agro-ecosystem types are discussed and compared. The 30 year jhum cycle has advantage over the 10 or 5 year cycle, in that apart from higher yield, monetary output/input ratio under a 30 year jhum cycle is advantageous over terrace cultivation as the latter needs heavy inputs of fertilizers. The main advantage of settled valley cultivation is the raising of crops consistent in yield year after year from the same site.

## CHAPTER 2

STUDIES ON ENERGY BUDGET IN SOME  
AGRO-ECOSYSTEM TYPES OF NORTH-  
EASTERN HILL REGION OF INDIA.

STUDIES ON ENERGY BUDGET IN SOME AGRO-ECOSYSTEM TYPES OF  
NORTH EASTERN HILL REGION OF INDIA

## INTRODUCTION

Increasing agricultural yields of the last half century was possible through industrialisation of agriculture, involving large fuel energy subsidies, sophisticated chemical control and high yielding crop varieties. Such an agriculture system requires a ten-fold increase in fertilizers, pesticides and horse power to double the crop yield. However, modern agriculture is highly unstable and has many environmental repercussions. Such agricultural systems are efficient in terms of human time and labour but are highly inefficient from an overall energetic point of view as from five to ten calories of fuel energy is required to produce a single calorie of food energy (Steinhart & Steinhart, 1974). An underdeveloped society cannot possibly afford expensive auxiliary energy inputs into agricultural systems under present economic situation. The obvious inapplicability of such systems as a model for development in an energy limited world has led to renewed scientific interest in traditional systems of agriculture as presumably offering greater ecological efficiency. In particular, shifting or swidden systems of cultivation have been held up as a model of productive efficiency where from five

to fifty food calories are obtained for each calorie of energy used in production (Bappaort, 1971; Steinhart and Steinhart, 1974).

In north-eastern India, slash and burn agriculture is a predominant form of agriculture and forms the source of livelihood for nearly 1.6 million tribal population. This practice locally called as 'Jhum' consists of cutting down the forests of various successional stages on the hill slopes, allowing the slash to dry for a few months and burning the slash before sowing mixed crops. The land is utilised for one or two years and then left as fallow to regenerating forest. The jhum cycle (the fallow period before the land is again cultivated) is often short ranging upto 4-5 years but in the traditional type the cycle may be as long as 20-30 years as was the case when the population pressure was not so great (Samakrishnan & Toky, 1978; Bamakrishnan et al. 1920).

Besides this, intensive rice cultivation is also done in the narrow valleys and flat lands between the mountainous slopes. Two crops of rice are annually taken, one between March and August and the second between August and November. The land is left as fallow during the winter months. Such an intensive rice cultivation is possible due to enrichment of the soil by nutrients washed down from the

hilly slope\*/ In recent times, there has been an attempt by governmental agencies to discourage jhum cultivation along the hill slopes and provide bench-terraced land to the farmers. Jhum and valley cultivations are traditional practices which represent the natural subsidised solar powered agricultural systems. These systems are completely different from highly fossil fuel subsidized agricultural systems of the more developed society. The only source of external energy is man power, and sometimes bullock power is also used as in valley cultivation. Traditional practices may provide the best base on which to develop effective production systems with minimum fuel subsidies. The survival of human population depends upon such agro-ecosystems that are stable and more productive.

The energetic aspect of traditional agriculture in India has not been studied except for a recent one by Mitchell (1979). Such a study on slash and burn agriculture and other agro-ecosystem as practised traditionally or in recent times has not at all been understood. The aim of the present study is to analyse energetics of jhum and valley cultivation as is done traditionally and to make comparisons between them and to contrast these with more recently introduced terrace cultivation. These three systems are available at Burnihat in the Khasi hills (26°.0 N & 91.5® E) and are practised by one of the local tribes namely the 'Garos\*. The area supports

mixed humid forests with an annual average rainfall of 220 cm. The terrain is hilly with steep slopes (angle ranging from 20° to 40°). The average size of the plot varies between 1.0 to 2.5 ha. for jhum, about 2 ha. for terrace and 0.2 to 0.3 ha for valley cultivation for an average family of two adults and three to four children.

#### METHODS OF STUDY

Jhum sites with 30, 10 and 5 year cycles were selected. Mixed cropping was done only for one year in all the three sites. Sites with valley and terrace cultivations were also selected in the same area. While, selecting the sites care was taken to ensure that the jhum areas had the same topographic conditions and all the sites were subject to least external disturbances due to wild animals like monkeys, wild pigs and elephants which are so common in the area. The economic yields in all cases were measured in the field. The total hours required by male, female and bullock for completing the various operations were calculated and converted into horse power (H.P. hours) by multiplying the number of hours of use of each source with the corresponding horse power. It was assumed that one adult man developed 0.100 horse power, one adult female 0.075 horse power and a pair of bullocks developed 1.000 horse power. Horse power hours

were converted into kilo-calories, assuming that one horse power is equal to 640 kilocalories of energy. The inputs of seeds in all the different agro-ecosystems and the input of fertilizer in terrace cultivation were converted into kcal. of energy by multiplying the various quantities of seeds and fertilizer with the standard caloric values given in Table 2.1. For calculating the output of energy under the three types of systems, the total economic yield of the various crops was converted into k.cal. of energy by multiplying with standard values of various edible parts of crops as given in Table 2.1. The energy efficiency of each system was calculated as the output/input ratio.

## RESULTS

### Energy budget in Jhum agro-ecosystem :

Besides solar power, man power is the only source of energy in jhum cultivation. Among all the agricultural operations, clearing the underbrush vegetation and felling trees and bamboos is the most *energy* requiring operation which is completed latest by the end of January. Sometimes this task is completed by the joint efforts of 2-3 families particularly when the jhum plot is larger. Under a 5 year jhum cycle, the total energy expended in this operation was 7488 k.cal./ha and it was 8.2 and 10.8 times more in 10 and 30 year jhum cycles resp., compared to a 5 year cycle.

Table 2.1.

Caloric value for different components utilized in the agro-ecosystem  
(values expressed as dry wt. caloric equiv.)

Category	Av.energy values (k.cal/kg )
Nutritive k.cal:	
<sup>1</sup> Grains	3,898
Pulses	3,887
i	
Sesamum	6,365
•^Castor	6,212
<sup>1</sup> Leafy vegetables	3,291
<sup>1</sup> Roots & tubers	3,292
<sup>1</sup> Pruits	3,570
<sup>2</sup> Pupae	5,852
<sup>2</sup> Cocoon (silk)	4,824
Production cost:	
<sup>3</sup> N	18,400
	3,335
<sup>3</sup> K <sub>2</sub> D	2,310

Gopalan et al., 1976

<sup>2</sup>Nakano & Monsi, 1968

<sup>3</sup>Pimentel et. al., 1973

Under 5, 10 and 30 year jhum cycles, the energy expended for this operation alone formed 11.2%, 46.15% and 41.8% resp. of the total energy required for all the agricultural operations during the year (Table 2.2).

The next step is burning the dried up slash. It is done during the last week of March. Burning is an important step in jhum cultivation. Burning not only disposes off all the plant debris but also liberates the mineral nutrients and improves the physical conditions of the soil for future crops. Much energy is not expended for the burning operation. It may be noted here that burning may be done twice under 10 and 30 year jhum cycles. The first burning involves easily combustible slash but large trunks of wood may have to be heaped up and burnt once again to complete the process. Under a 30 year jhum cycle the energy involved in burning was estimated to be 6,720 k.cal./ha which was nearly the same under a 10 year cycle. In a 5 year cycle, however, since plant biomass is chiefly due to weedy herbs and a few shrubs, one burning was sufficient and hence the energy expended was almost 1/10th of the other two jhum cycles (Table 2.2).

After burning and with the onset of monsoon, a mixture of 8-15 crop species is sown simultaneously. Cropping

Table 2.2.

Energy inputs (k.eal./ha/yr) for agriculture under different jhum cycles

Agricultural operation	Energy input (k.cal./ha/yr) under jhum		
	30 yr cycle	10 yr cycle	5 yr cycle
A.Labour input (total):	193,728	135,872	66,560
Clearing under Storey vegetation	26,112	31,424	7,488
Felling trees & bamboos	55,040	30,080	-
Collection of debris & burning	6,720	4,608	640
Dibbling, broadcasting & Transplantation	6,144	6,720	6,720
Hut Construction	,3,584	3,584	3,584
Weeding	S, 448	10,112	11,520
Watching of the field from wild animals	11,968	11,968	10,688
Rearing caterpillars	18,880	-	-
Harvest	24,640	26,112	22,720
Transportation	35, 84	2,048	1,600
Threshing	11,712	3,776	640
Shelling	16,896	5,440	960
B.Seed input	204,132	175,396	174,617
C.Total energy input into the system	397,860	311,268	241,177

Any idea of variation?  
 Would rounding of the figures be more appropriate to the accuracy?

is usually done for one year after which the land is left as fallow. Under a long jhum (30 year), cereals constitute the major component usually with some pulses, fruit and leafy vegetables. The seeds of all the crops account for an energy input of 204, 132 k.cal/ha. Under short jhum cycle (5 year), sesamum, leafy vegetables, semi-perennial and perennial crops are emphasized, cereals being sparsely sown and with an input of 174, 617 k.cal./ha. through seeds. Under a 10 year jhum, the cropping pattern was intermediate between the other two cycles, with an input of 175,396 k. cal/ha. through seeds. Under jhum cultivation, seeds form the major input of energy which forms 51.3%, 72.4% and 56.3% of the total energy expended under 30, 10 and 5 year jhum cycles resp. (Table 2.2) The seeds of sesamum, Setaria italica. pulses and cucurbits are broadcast, maize and rice are sown by dibbling, cassava through stem cuttings and banana, eolocasia and ginger through transplanting the rhizomes. They are all energy demanding operations and it was estimated that the energy expenditure on this account was 6144 k.eal./ha. under a 30 year jhum cycle, and 6720 k.cal./ha. under 10 and 5 year jhum eycles.

Weeding is another energy consuming task, perform performed by the women folk. However, the total energy

expenditure was minimum under a 30 year cycle, and it accounted for 8,448 k.cal./ha. for two weedings during the cropping period. Under 10 and 5 year cycles, weeding is more laborious and the energy expended for two weedings, increased 1.2 and 1.3-fold under 10 and 5 year cycles respy. as compared to a 30 year cycle. Under short jhum cycles, Imperata cylindrica with its extensive underground rhizome was a serious problem along with Eupatorium odoratum and this would explain high energy expended in weed control.

Harvesting extends over a long time period and starts with the ripening of maize and Setaria italica in the month of July and continued upto January till the harvesting of perennial crops (Toky & lamakrishnan, unpublished). The energy requirements for this under different cycles range between 22,720 and 26,112 x.cal./ha. However, the j( of human energy expended for the three types of jhum  $\pm$ ficreased<sup>N</sup>with shortening of the jhum cycle (Table 2.2). "~~~~" *JUu\*\*\*\**

Threshing and shelling of rice is done during winter months mainly by female members of the family. The energy expended for this function is the lowest in a 5 year jhum cycle followed by a 10 year cycle and is the highest for a 30 year cycle. This is obviously related

to the yield of rice crop (Table 2.2).

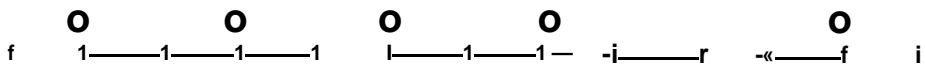
The pattern of distribution of labour into shifting agriculture under a 30 year cycle is shown in Fig. 2.1, which also is the basic pattern for other jhum cycles. There is only one peak period of labour input during January-February, at the time of slashing the vegetation. Rest of the year, the work is light and is uniformly distributed. During part of February, March and December, the farmers have no work in the field.

The total input of energy through all the agricultural operations and also through the seed was minimum under a 5 year cycle and this was 1.3-fold and 1.6-fold higher under a 10 and 30 year cycles. It is interesting that in comparison to this pattern of input, the economic yield in a 5 year cycle is the lowest and under 10 and 30 year cycles there is little difference in the economic yield which is about 2-fold of that under a 5 year cycle. In general, while the longer Qhum cycles emphasized on grain and seed crops as is seen from the yield data, the short ahum cycles in contrast showed higher yield of root and vegetable crops. The output/input ratio is the lowest in a 5 year cycle followed by a 30 year cycle, and is the highest in a 10 year cycle (Table 2.3 and Fig. 2.2).

Fig. 2.1, Comparison of the distribution of labour energy over the year in an agro-ecosystem under a 30 year Jhum cycle and under valley cultivation.

Dark column, 30 year Jhum cycle; Open column, valley cultivation.

Labour energy input U.cal./ha./yr. (x 640)



T| -

< ; r

**t**

o

v)

**r**

Fig. 2.2. Comparison of energy outputs from various crops under 30, 10 and 5 year. Jhum cycles.

Dark column, 30 year cycle; Hatched column, 10 year cycle; Open column, 5 year cycle.

1, Oryza sativa; 2, Sesamum indicum; 3, Zea mays; 4, Setaria italica; 5, Musa sapientum; 6, Hibiscus sabdarifa; 7, Manihot esculenta; 8, Colocasia antiprurum; and 9, Cucurbits.

Yield k.cal /ha/yr (X 10<sup>5</sup> )

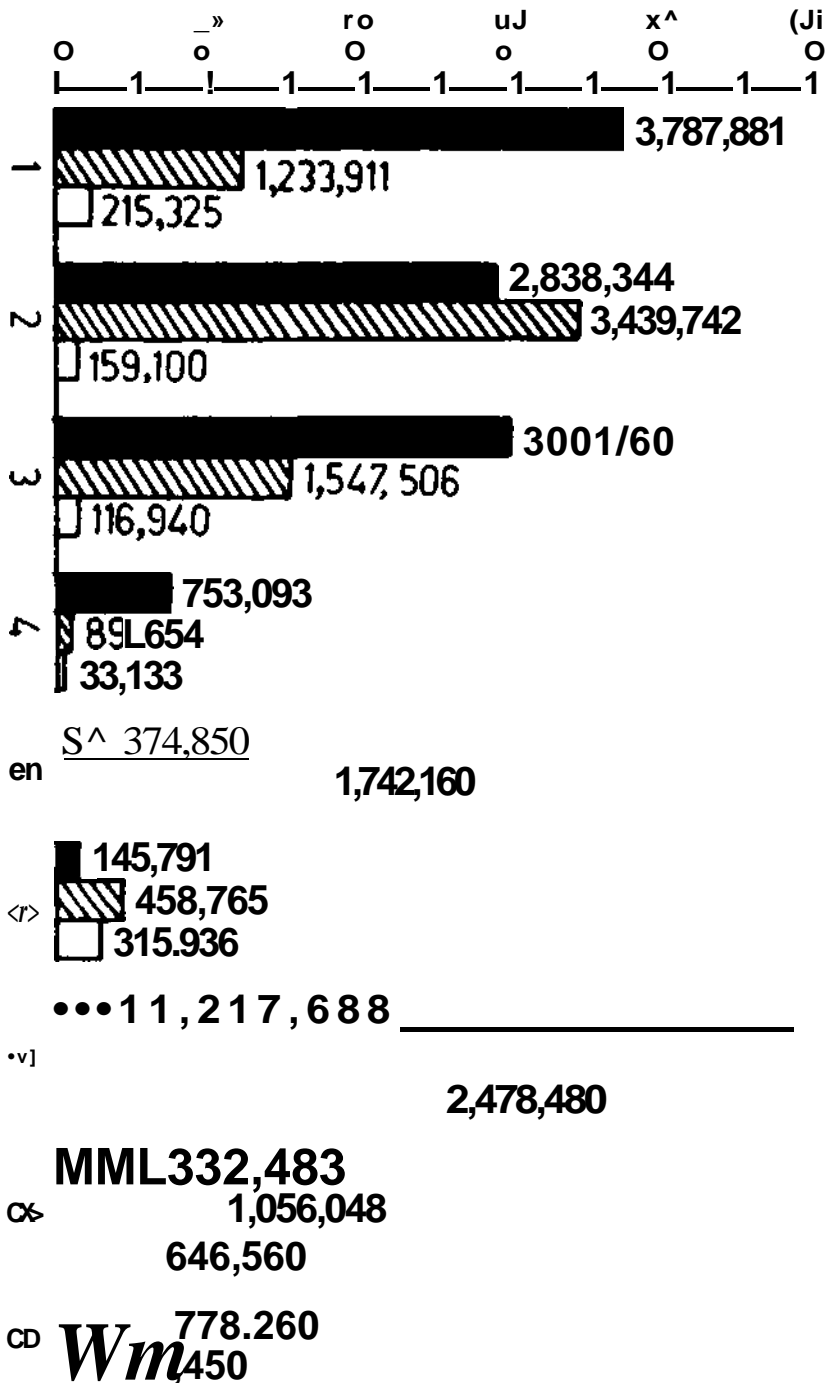


Table 8.3.

Energy ratios in agricultural systems - jhum, terrace  
and valley cultivation

Agricultural system	Energy k.cal/ha/yr		Output/Input Ratio
	Input	Output	
Jhum			
30 year cycle	397,860	13,580,492	34.13
10 year cycle	311,268	13,540,945	43.50
5 year cycle	241,177	5,707,634	23.66
Terrace			
	1,715,758	10,431,062	6.07
	(1,843,758)		(5.65)
Valley			
I crop	258,312	6,133,737	23.74
II crop	231,496	5,970,566	25.79
I + II crop	489,808	12,104,303	24.71

Figure in parentheses indicate values for  
the first year of terrace cultivation.

Energy budget in valley agro-ecosystem j

Unlike mixed cropping in jhum cultivation, valley cultivation is a monoculture of rice alone. Further, this is a sedentary form of agriculture. Two crops are annually taken from the same land, as the land is comparatively more fertile and does not need any fertilizer application. Field preparation for the first crop is done in February-March. Preparation of field is done manually using bullocks. Seedlings raised in nursery beds in the month of March are transplanted in the beginning of April, and the harvesting is completed by the end of July or early August. Immediately after the first harvest, the fields are again prepared for the second crop in August. Seedlings already raised in nursery beds in the month of July are transplanted in the field plots in the month of August itself and harvesting is completed by October-November. Subsequently, the land is left a fallow between November and March. Most of the agricultural operations like weeding, transplanting, harvesting, threshing, shelling etc. are done manually.

Energy budget involved in valley cultivation is given in Fig. 2.3. In valley cultivation, the preparation of field for the two crops is the most arduous task and this alone involved an energy expenditure of 41.0% of all the operations.

Weeding is done twice for each crop and this formed the second major labour input with an energy expenditure of 25% of the total. Threshing and shelling required another 16.7% of the total human energy input. During the first and second crops, the energy supplied into the system through the seeds was found to be 26.5% of the total energy input.

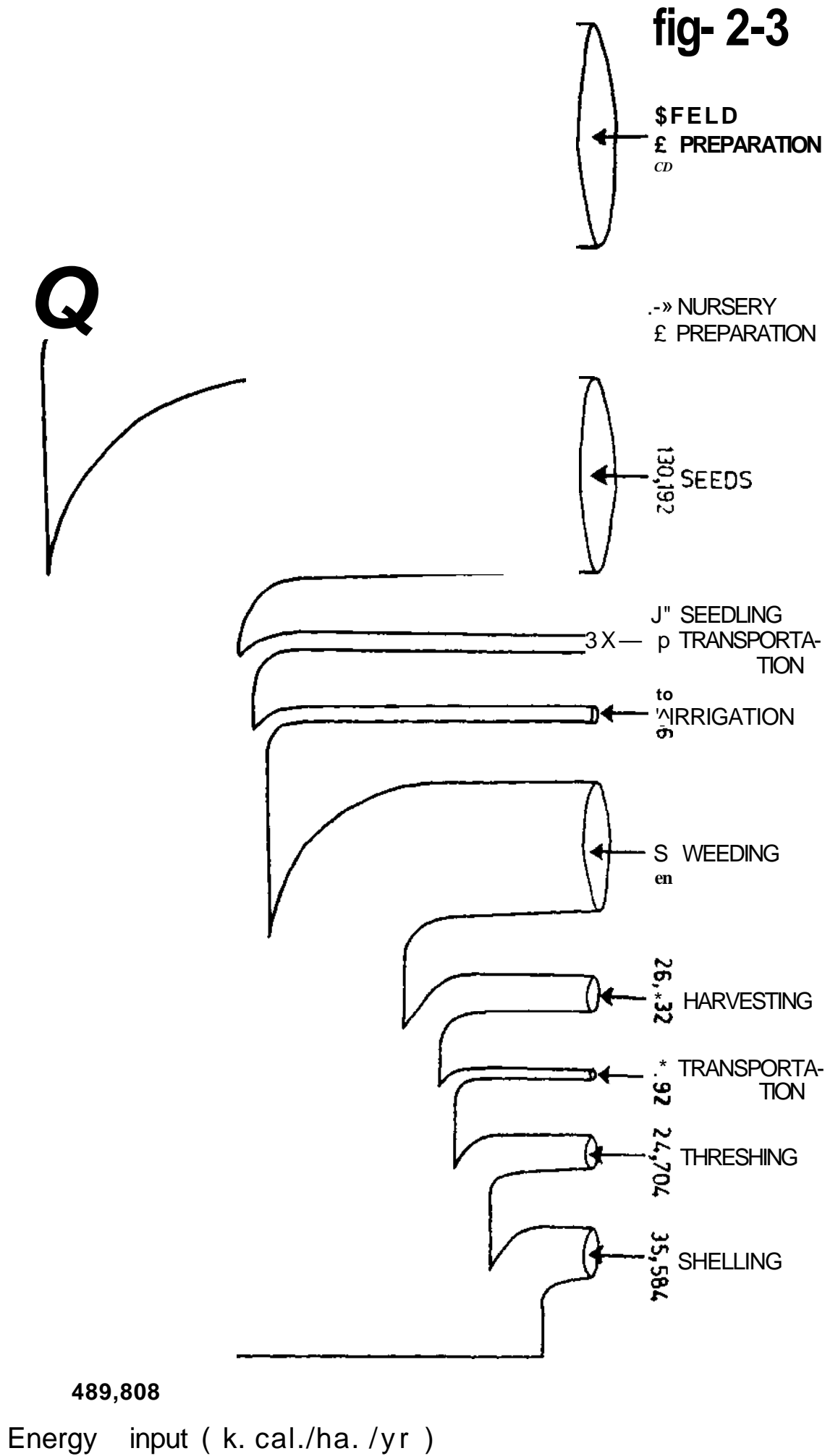
The total input of energy during the first crop was slightly higher than that under the second crop (Table 2.3).

Valley cultivation is a labour intensive farming system with six peak periods of labour requirements during the year for field preparation and weeding, during a period of about 3 months only in a year. For the remaining 9 months in the year the farmers have very little work (Fig. 2.1).

The economic yield from two crops in valley cultivation is almost equivalent to the yield from that under a 10 or 30 year jhum cycle. The total energy input through labour and seed for the two crops, however, is somewhat higher for valley cultivation than that under jhum. The output/input ratio, therefore, works out to be much lower for this

Fig. 2.3. Major energy inputs (k. cal./ha/yr)  
for raising two crops under valley  
cultivation.

**fig- 2-3**



agriculture type compared to that under 10 and 30 year jhum cycles (table 2.3).

Energy budget in terrace agro-ecosystem :

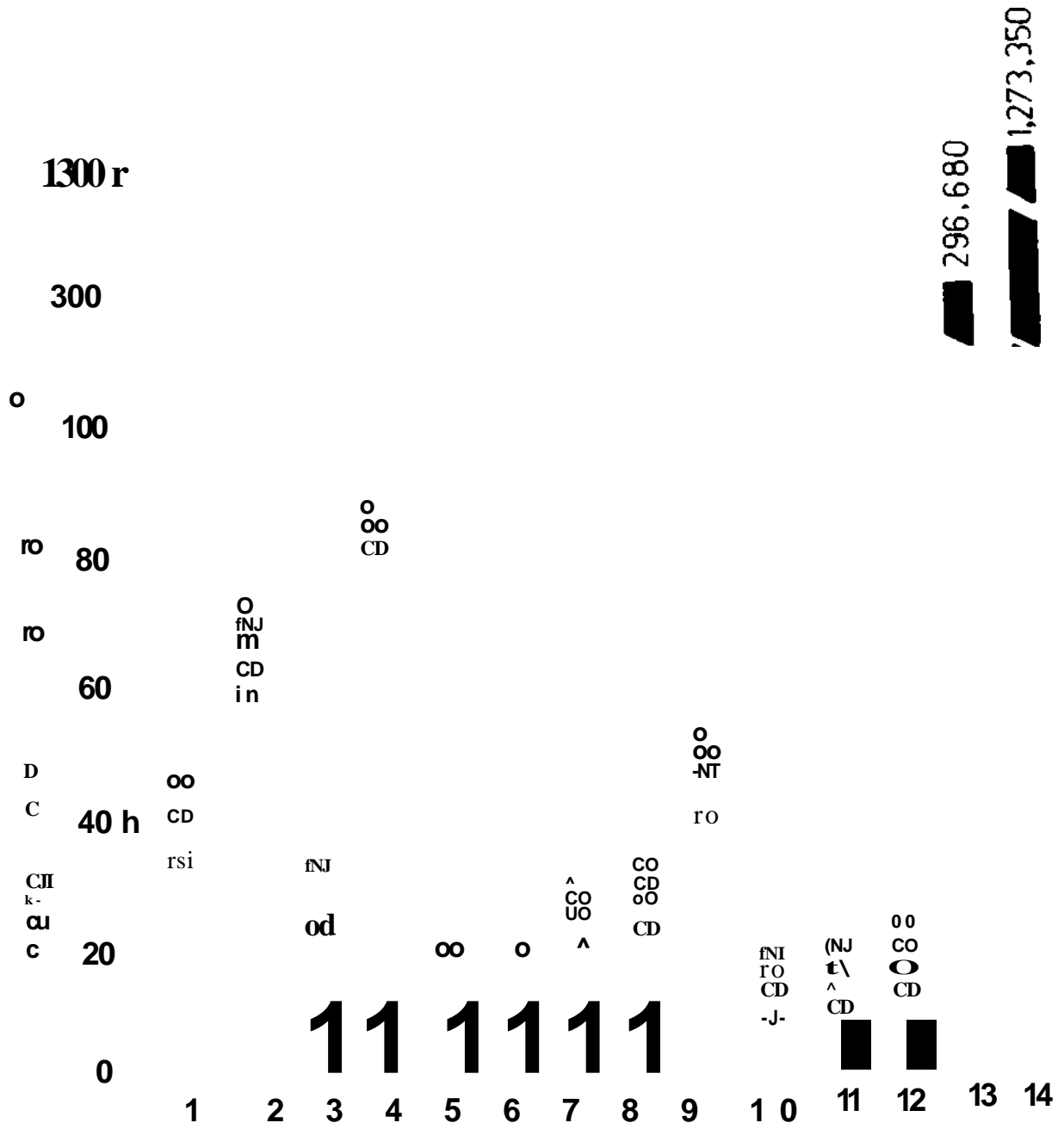
Terrace cultivation studied here was in some ways similar to jhum cultivation in that mixed cropping is a *common* feature. As many as 14 crops may be raised together and harvested sequentially as under the jhum cultivation. However, monoculture under terrace is also quite common, a major point of difference from jhum is with respect to heavy input of fertilizer and the cost of terracing the land during the first year. The total energy requirement in terracing the land was estimated to be 128,000 k.cal./ha. This also included the labour required for clearing and felling the forest before terracing the land. During subsequent years the energy needed for clearing the land of weeds and repairing the terraces before dibbling the seeds requires only 27,648 k.cal./ha. which is approximately the same as for weeding under a 30 year jhum cycle (Fig. 2.4). The heavy input of fertilizer required for terrace cultivation accounted for a major input of 1,273,350 k.cal/ha/yr. and was 74.2% of the total input into the system.

Fig. 2.4. Major energy inputs (k.cal./ha/yr) for terrace cultivation.

1, Clearing under storey vegetation;  
2, Pelling the trees and bamboos; 3,  
Collection of debris and burning; 4,  
Terrace preparation; 5, Dibbling,  
broadcasting and transplantation; 6,  
Weeding; 7, Watching the field; 8,  
Silkworm Caterpillar rearing; 9,  
Harvest; 10, Transportation; 11,  
Threshing; 12, Shelling; 13, Seeds  
and 14, Fertilizers.

2, 3 & 4 felling trees, debris  
collection and terracing respy.  
in I year only.

fig. 2-A



The economic yield of grain and seed crops under this cultivation was almost 1/3 of that under a 30 year jhum cycle but the yield of fruits and vegetables and tuberous and rhizomatous crops was higher than that under a 30 year jhum cycle. The energy input into this system is very high compared to all others but the output is lower than that under a 30 or 10 year jhum cycle and hence the output/input ratio works out to be the lowest. This ratio is lower in the first year of terrace cultivation compared to subsequent years in view of additional labour input necessary for terracing in the first year (Table 2.3, 2.4).

#### DISCUSSION

##### Jhum agro-ecosystem :

As noted earlier jhum (slash and burn agriculture) forms the main agro-ecosystem type with a 5 year cycle being the most prevalent, and 10 and 30 year cycles are rare events because of increased population pressure. The energetic efficiency obtained under a 30 year jhum cycle was lower than that under a 10 year cycle because the input of energy in the form of cutting the forest was higher for the former while the output of energy was almost

Table 2.4\*.  
Energy outputs under terrace cultivation

	Crop Species	k.cal./ha/yr
Grain & Seed Crops	Oryza sativa	3,115,788
	Sesamum indicum	130,462
	Zea mays	561,312
	Phaseolus mungo	27,209
	Ricinus communis	49,696
	Musa sapientum	642,600
Leafy & Fruit vegetables	Hibiscus sabdarifa	297,830
	Cucurbita maxima	339,150
	Momordica charantia	33,915
	Phaseolus vulgaris	53,550
Tuber & Rhizome Crops	Manihot esculenta	4,698,336
	Colocasia anticuprum	323,280
	Zingiber officinalis	79,024
	Curcuma longa	58,549
Silk worm	Cocoon (silk)	19,296
	Pupae (without cocoon)	1,060

*beans are  
(see Table 1.5 for  
comparison).*

equal in both the cycles. It may be worth noting here that the older forests are more exposed to wild animals such as monkeys, wild pigs and elephants which may lower the output by damaging the crops. Further, an extra labour input may be required for guarding activities. For these reasons Conklin (1957) working in Philippines also advocated clearing of secondary forests rather than mature ones. A 10 year jhum cycle seems to be ideal as it not only gives sufficient time for recovery of soil nutrients (Hamakrishnan et al<sub>t</sub> 1980; Toky & Hamakrishnan, unpublished) but has optimum energy efficiency. However, a 30 year cycle may have greater merit for environmental reasons. uwfiw\*\*\*" . . .

Although the energy expenditure under, a 5 year jhum cycle was minimum among all the three cycles studied, the economic yield was also low.^ For this reason the energy efficiency of this system works out to be the lowest. The reduction in output under a 5 jtear cycle may partly be due to poor nutrient recovery of the soil (Toky & Ramakrishnan, unpublished) and also because of serious weed problems. It may be noted here that under such short cycles weeds like Imperata, cvlindrica and Bupatorium odoratum take, over the site and the secondary succession gets arrested (Hamakrishnan et al<sub>f</sub> 198G). Also weeding required an extra expenditure of energy under a 5 year jhum cycle. Probably due to low

fertility of the soil which may not sustain cereal crops, starchy crops like banana and cassava are grown under short cycles and therefore the quality of food is also inferior.

The pattern of energy expenditure under *hvm* indicates that the farmer has work to do for most of the year. However, the work is light and therefore he is mostly underemployed.

Data on the energetics of shifting agriculture is rather scarce. Bappaport (1971) provides relatively complete information on the energy expenditure of the Tsembaga people of New Guinea Highlands. According to his data of human labour expenditure and crop yield, the farmers obtained an average of 16 food calories for each calorie of human energy employed during farming which may go up to 20 under more favourable conditions. Our study indicates much higher values (output/input ratio of 43.5) for efficiency as seen from a 10 year cycle, with the values ranging from 23.66 to 43.50 under the three cycles. Thus from an energy point of view this seems to be the best evolved system for forested areas in tropics and subtropics (Conklin, 1957; Bye & Greenland, 1960; Carneiro, 1960).

While calculating the energetic efficiency of shifting cultivation, a major energy input, however, could not be

taken into consideration. This is the plant biomass which is burnt before cultivation. Eambo (1978) taking the energy data of Bappaort (1971) for the Tsembaga agricultural system calculates that if the fire energy is included as an input, then in a plot cleared from secondary forest the output/input ratio may drop to 0.11. For the mature forests this ratio was calculated to be even less. According to him, 10 to 30 energy calories are expended for each calorie obtained under swidden farming and therefore it is just as dependant on energy subsidy to achieve high production as in modern agriculture. However, like human energy which for all practical purposes is cheap and free, no special effort is expended in obtaining plant biomass which regenerates rather quickly in the jhum fallow using only the available natural resources.

If fire through plant biomass is not included here as an input, the various secondary economic products from the jhum fallows are also not included as outputs from the system. From the early successional fallow Imperata cylindrica commonly known as thatching grass is used for hut building. Bamboo which has a wide variety of uses as fencing and building material, fuel, etc is also harvested

from the jhum fallows. It may be noted that bamboo attains its peak development as a member of the secondary successional community upto an age of 20 years after the land is returned to the forest. Fire wood from small trees and shrubs constitutes another major output.

#### Valley agiro-ecosystem s

From the energetics point of view, valley cultivation was also very efficient though less than under 10 and 5 year cycles. This is due to heavy labour input for field preparation and weeding. Weeding is particularly a serious problem partly due to increased weed vigour in a nutrient

*K*

enriched soil brought from the hill slopes. Further it is probable that large quantity of seeds may also be washed down from hill slopes that is under a short jhum cycle. The main advantage of this agro-ecosystem lies in the fact that external input of energy other than labour is not required and that this is a sedentary agricultural system which permits raising of two crops every year because of high soil fertility and water availability.

#### Terrace agro-ecosystem :

Heavy input of fertilizer along with labour for terracing in the first year makes this system very inefficient

# n

from energy budget point of view, though the output is approximately the same as under 30 or 10 year jhum cycles. This system is comparable to comparatively modern Indian agricultural systems where 9 calories of food are harvested for each calorie of fossil fuel energy^ut into the system (Mitchell, 1979) and better than most western agricultural systems where the yield is 1 Or 2 calories of food per calorie of input (Spedding & Walshingham, 1976). But this system is not a stable one. Even if soil erosion is checked to some extent due to terracing, infiltration lossessf may still prove to be very heavy (Ramakrishnan et ajL, 1980). Purther, heavy input Gf fertilizers in such a high rainfall region may prove to have serious environmental problems. For these reasons, terrace cultivation has not found much favour with the tribal population of the region. Infact, there is a tendency to switch back to *ihxm* after a few years of terracing, in spite of the fact that various Governmental agencies do the terracing for the farmers, free of cost.

On the basis of the data presented here and elsewhere (Toky and Ramakrishnan, unpublished) it is concluded that : (i) a 10 year jhum cycle is the minimum



desirable fallow period for sustaining shifting agriculture in this region from the point of view of energetic efficiency and soil fertility recovery, (ii) cereal cultivation should as far as possible be confined only to valley lands, (iii) terracing does not seem to offer a solution to the problem in view of heavy external energy required to sustain the same and the low yield inspite of such heavy inputs. Further, large scale terracing is also not desirable from an environmental point of view, in view of the fact that it is so . essential to maintain natural ecosystems in the Himalayan region. Any damage done to hill ecosystem in the Himalayan and adjoining hill regions may not only create environmental problems in these regions but also may have great repercussions in the northern plains of the sub- , > continent due to large scale flooding.

#### SUMMARY

^ ^U^,

The present study is a comparison of the energetic efficiency of three types of shifting agriculture locally known as 'jhum\*' in North-Eastern India. A 30 year cycle which is rather rare now is compared with the more common 10 year and 5 year cycles of the present time. Due to population pressure and land available the 5 year cycle is more common. A 10 year cycle is most efficient from energetic point

Of view and the output /input ratio here is 43.50 compared to 34.13 under a 30 year cycle and 23.66 under a 5 year cycle. Energetics of jhum is also compared with valley cultivation of rice as well as mixed cropping on terraces which was tried out as an alternative to jhum. Though the efficiency of valley cultivation is closer to a 5 year jhum cycle, it is self-sustaining year-after-year due to natural drainage of moisture and nutrients into the valley, the only energy input being in the form of labour which is cheap. The energy output/input ratio for terrace cultivation is very low due to high fertilizer input into the system and also due to labour input for preparation of the land.

## CHAPTER 3

SPECIES DIVERSITY, BIOMASS, LITTERFALL  
AND PRODUCTIVITY PATTERN DURING SECONDARY  
SUCCESSION SUBSEQUENT TO SHIFTING  
AGRICULTURE (JHUM) IN NORTH-EASTERN INDIA.

Species diversity, biomass, litterfall and productivity patterns during secondary succession subsequent to shifting agriculture (Jhum) in north-eastern India

#### INTRODUCTION

Over large areas of north-eastern India there shifting agriculture (locally called Jhum) is practised; secondary succession over abandoned farmland provides the mean of rehabilitating land for renewed cropping. Shifting agriculture relies on the structure and composition of the fallow vegetation to indicate the site potential and the extent of soil fertility and this is the key to the long-term success of this practice. If the fallow period is too short (4-5 years) which is very common at present times due to pressure on cultivable land, site degradation takes place and yields decline (Toky & Ramakrishnan, unpublished).

Many aspects of ecosystem organization would be better understood through studies on plant succession. Some of the most important functions of developing communities are their productivity changes, the consequent biomass accumulation, its return to the upper soil layer through litterfall and its decomposition which accounts for a large part of restoration of fertility. These processes have received some attention in various parts of the humid tropics, e.g., in Thailand

(Zinke, Sabhasri & Kunstadter, 1970); in Africa (Bartholomew, Meyer & Laudelot, 1953; Laudelot & Meyer, 1954; Greenland & Kowal, 1960; Nye & Greenland, 1960) and in tropical America (Snedaker, 1970; Harcombe, 1973; Ewel, 1976), but no information on these aspects exists for secondary successional communities developing after jhum in north-eastern hill areas of India. Further, there seems to be considerable confusion related to diversity, productivity and stability of successional communities. A general model of community structure and function was developed by Margalef (1961, 1969) and Woodwell and Smith (1969) but very few of the generally accepted hypotheses have been tested experimentally (Odum, 1969).

The objectives of the present studies are to describe in detail the pattern of secondary succession on the abandoned jhum fields; measurement of biomass, productivity and litter production and their relationship over the first 20 years of community development and their comparison with a 50 year old fallow. All these studies were done at Burnihat (located in Khasi hills of Meghalaya at 26.0°N & 91.5°E) under sub-tropical humid but with monsoonic climate, obtaining an annual average rainfall of 220 cm, most of which comes during May to October. The

winter is mild and dry extending from November to mid-February but with a few scattered showers. A brief dry summer from mid-February to April precedes the monsoon, The soil is slightly acidic and is of lateritic origin.

#### METHODS OF STUDY

Vegetation analysis and studies on biomass and litterfall were done in jhum fallows of 1,5,10,15 and 20 years of age. The size of the fallow ranged from 2 to 2.5 hectares on hill slopes of 20° to 40°. While selecting different fallows, care was taken to ensure similar topography and exposure conditions. All the fallows were developed on land under a 0.0 *yhar* jhum cycle so that the pattern of vegetation development was similar in all sites.

Vegetational analysis of the jhum fallows was done by quadrat method. 30 Quadrats of 100 m<sup>2</sup> size for trees and shrubs, and 1 m<sup>2</sup> size for the herbaceous species were laid along a transect down the slope. The importance value index (I Y I) which is an integrated measure of the relative frequency, relative density and relative basal area, was calculated (Misra, 1968; Kershaw, 1973). Species diversity was calculated using formula given by Margalef (1968) as :

$$* - * \& ) * 1 \& ) ] .$$

where,  $H$  = Shannon index of general diversity,  $n_i$  = Importance value index of each species and  $N$  = Total importance value of all the species. In order to evaluate the index of dominance of the community, the formula of Simpson (1949) was used as :

where,  $G$  = Index of dominance,  $n_i$  = Importance value of each species and  $N$  = Total importance value of all the species.

For collection of litter, ten litter traps of  $p$  1 m size were randomly laid out in each site. The litter was collected at monthly intervals from August 1978 to July 1979. The litter was classified into leaves and twigs and farther sub-divided into specific categories. The litter was dried at  $80^{\circ}\text{C}$  and weighed.

Biomass of herbs and shrubs and few tree samplings which constituted the vegetation in 1 and 5 year fallows was determined by harvest method. During October and early November 1979, when they were at their peak of vegetative growth, all The above ground species were clipped at the ground level. Clipped material was sorted out into different categories, oven dried at  $80^{\circ}\text{C}$  and weighed. 15 quadrats of  $1\text{ m}^2$  size along a transect along the slope were sampled for this purpose.

The fallows of 10, 15 and 20 years of age were dominated by bamboo (Dendrocalamus hamiltonii) along with some dicot tree species. While harvesting the above ground biomass of bamboo, the shoots were divided into seven diameter classes at 2 cm intervals from 7 cm to 19 cm. Five replicate bamboo shoots of each diameter class were cut at the ground level and fresh biomass was obtained separately for bole, branches and leaves. Dry weight was calculated on the basis of weight obtained on samples dried at 80°C. Average shoot density of each diameter class was used as the basis for calculating the total biomass per hectare. In estimating the above ground biomass for trees, allometric regressions (Fewbould, 1967) between dbh and various biomass components as shown in the Table 3.1 were used. For regression equations sample trees of various diameter classes from 3 cm to 15 cm were harvested and dry weight determined separately for bole, branches and leaves. Annual biomass increase for each stand was determined by dividing the difference between the standing biomass of two consecutive fallows with the time difference in year/. Annual net primary production of each stand was calculated by adding the total litter production over a year into the annual increase in aerial biomass.

Table 3.1  
Correlation co-efficients (r) and allometric regression equations for  
different components of dominant tree species in a 20 year fallow.

Tree Species	Bole	Branches	Leaves
Dillenia indica	Y=-12.833+3.864 X r=0.990	Y=-7.943+1.497 X r=0.902	Y=-1.234+0.451 X r=0.970
LageiCstroemia parvi\J»m	Y=-21.845+5.046 X r=0.948	Y=-4.521+1.92 X r=0.933	Y=-1.398+0.488 X r=0.956
a arborea	Y=-15.432+3.990 X r=0.941	Y=-6.434+1.382 X r=0.920	T=-1.864+0.543 X r=0.900
Bauhinia alba	Y=-14.440+4.880 X r=0.931	Y=-3.615+1.548 X r=0.901	Y=-1.534+0.651 X r=0.932
Oallicarpa macrophylla	Y=-10.932+3.020 X r=0.901	Y=-3.783+1.240 X r=0.912	Y=-5.540+1.201 X r=0.956
Vitex peduncularis	Y=-18.400+5.100 X r=0.954	Y=-2.845+1.258 X r=0.994	Y=-1.546+0.562 X r=0.932
Schima wallichii	Y=-15.320+4.980 X r=0.980	Y=-4.312+1.68 X r=0.960	Y=-2.185+0.743 X r=0.934
Cedfelja toona	Y=-10.436+2.846 X r=0.980	Y=-8.472+1.593 X r=0.934	Y=-1.346+0.551 X r=0.980
Terminalia bellerica	Y=-20.905+4.080X r=0.961	Y=-9.749+1.747 X r=0.957	Y=-6.530+1.119 X r=0.948
Albizzia procera	Y=-13.840+5.021 X r=0.952	Y=-4.685+1.342 X r=0.943	Y=-1.584+0.361 X r=0.902
Titex glab^rata	Y=-12.594+3.860 X r=0.900	Y=-5.147+1.210 X r=0.910	Y=-1.734+2.580 X r=0.950
Wrightia tomentosa	Y=-17.840+5.341 X	Y=-2.358+1.158 X r=0.932	Y=-1.294+0.487 X r=0.976

I = Diomas \* (icg)  
X = dbh (cm)

r = correlation co-efficient

## RESULTS

Secondary succession pattern;

The pattern of secondary succession and the rapidity with which forested community develops depends upon the degree of destruction and the clearing of underground propagules of the community that existed prior to this operation. The length of the jhum cycle also determines the pattern of vegetation development. The pattern of secondary succession in the fallows during the first 3<sup>w</sup> ye<sup>a</sup>s when weedy species dominate varies considerably depending upon the jhum cycle and the intensity and duration of cropping as follow:

- (i) Supatorjum dominated fallow - where the cycle is either long or short and underground rhizomes are destroyed by constant weeding during cultivation, particularly when cultivation is done for more than one year,
- (ii) Imperata dominated fallow - particularly under shorter cycles, Imperata cylindrica rhizomes are abundant in the soil and this species coexists with Eupatorium odoratum.
- (iii) Mikania dominated fallow - under shorter cycles and where M. micrantha is abundant in the area, this may choke the fallow and other herbaceous and shrubby weeds particularly due to its growth habit. This species forms a

**thick mat** on the ground, striking roots wherever they come in contact with the soil.

(iv) 3a no ha rum dominated fallow - .§. spontaneum grows less frequently at Burnihat as compared to the Garo and the Mizo hills. It dominates under short cycle conditions where cropping is usually for not more than one year and therefore weeding of rhizomes is not thorough.

(v) Borreria dominated fallow - B. hispida is a stoloniferous species having both prostrate and erect branches and rooting at nodes. It forms an interwoven mat and checks the seedling establishment of other species. It usually grows where Imperata cylindrica and Eupatorium odoratum are weeded out from time to time.

(vi) Bamboo dominated fallow - under 10-15 year cycle, when cropping is done only during the first year rhizomes of bamboo (Den/irocalamus hamiltonii) remain in the soil and sprout. Due to the more rapid growth of bamboo sprouts, they soon suppress other herbaceous weeds. With constant weeding of sprouts for more than two years, the rhizomes of this species may be killed.

(vii) Tree dominated fallow - under longer jhum cycles, if the cropping is done only for one year and the stumps of the trees are not destroyed; the stump sprouts form a close canopy

within 4-5 years of abandonment and weedy species are fast eliminated. This pattern favours a faster development of a forested cover.

The common and the/general pattern of secondary succession at Burnihat is given in (Tables 3.2, 3.3). It starts with the abandonment of field under a short jhum cycle of about 5 years. In such a situation, the early colonizers, Eupatorium odoratum and Imperata cylindrica dominate the fallow upto a period of 5 years. Imperata cylindrica, also an indicator of fire has the strategy to withstand fire due to extensive underground rhizomes, which sprout to produce aerial shoots as soon as favourable conditions occur. In a freshly burnt area, the density of this species may be as high as 100 plants/m<sup>2</sup>. Imperata cylindrica also reproduced through seeds and this is favoured by constant cutting of the aerial shoots of this species (Saxena & Hamakrishnan, unpublished). Eupatorium odoratum on the other hand, diverts most of its resources for heavy seed production. This species also has efficient seed dispersal mechanism by wind due to the light seed and the pappus production. Both these features contribute to its success as a weedy colonizer.

The early colonizing herbaceous species discussed

Table 3.2

171 values of dominant species in successional communities developed after slash and burn agriculture (Data on 50 year fallow based on J. Singh, unpublished).

3MS1&3L	Age of fallow (years)					
	<u>1</u>	<u>5</u>	<u>10</u>	<u>15</u>	<u>20</u>	<u>50</u>
Bupatorium odoratum	175.2	179.5				
Imperata cylindrica	93.5	65.0				
Panicum khasianum	8.5					
Setaria glauca	5.5					
Gf-ewia elastica	4.5					
Cyperus glebosus	2.5					
Panicum maxima*	1.5	9.5				
Pious hispida	1.5					
Arundinella bengalensis		15.3				
Callicarpa macrophylla		7.5	28.0		10.1	
Dendrocalamus hamiltonii		7.0	175.0	154.3	136.8	10.0
Carex cruciata		6.9				
Bauhinia alba		D.<&	15.1	7.8	12.7	
Antedesma diander			9.3			
Dillenia indica			9.3	22.9	28.3	
C#r/a arborea			8.0	10.7	55.8	
Phyllanthus emblica			7.5			
Wrightia tementosa			7.5			

## Gcmtd...

## Speeles

	10	<u>15-</u>	<u>20</u>	50,
Vitex peduncularia		52.3	21.4	23.0
Ternstroemia belleria		21.0		
Albizia preera		10.6		
Vitex glaberata		5.8		
Sebania walllohi			12.3	32.0
Gedrelia toona			9.0	
Melia arborea				30.0
Castanopsis indica				27.0
Geranium oswa				25.0
Bugenia communis				13.0
Praon aainata				10.0
Psychotria sp				9.0

Table 3.3

General pattern of secondary succession in abandoned fields after slash and burn agriculture (values in parentheses are IVI values of dominant **speciea**)

Fallow age (years)	Community		
1	Eupatorium odoratum (175.2)	Imperata cylindrica (98.5)	- Panicum khasianum (8.5)
5	Eupatorium odoratum (179.5)	Imperata cylindrica (65.0)	Arundinella bengalensis (15.8)
10	Dendrocalamus hamiltonii - (175.0)	Gallicarpa macrophylla - (28.0)	"Bauhinia alba (15.1)
15	Dendrocalamus hamiltonii - (154.3)	Vitex peduncularis (52.3)	Dillenia indica (22.9)
20	Dendrocalamus hamiltonii - (136.8)	Oerya arborea (55.8)	- Dillenia indica (28.3)
50	Schima wallichii (32.0)	Melia arborea (30.0)	- Gastanopsis indica (27.0)

above dominate the community upto 5 years and then are replaced by Dendrocalamus hamiltonii which also survives fire through rhizomatous underground stems with stored reserve food. This is a dominant species in 10 to 20 year fallows (Table 3.2). The broad picture of the population dynamics of D. hamiltonii is given in Table 3.4. This species progressively becomes dominant and reaches its peak in terms of both frequency and density in a 20 year fallow. Regeneration of shoots increased upto 15 years and declined in older fallows. The percentage of dead individuals progressively increased and reached a maximum in a 50 year fallow. The reproduction through seeds is restricted and occurs only once during the life cycle of this species.

In 15 and 20 year fallows the dominance is shared by many shade intolerant broad leaved dicot tree species, which come through seedlings, root and stump sprouts. The common species are Vitex peduncularis, Oareya arborea, Dillenia indica, Terminalia bellerica, Bauhinia alba, Vitex glabtrata, Schima wallichii, Wrightia tomentosa and Cedrela toona.

In a 50 year fallow, besides a few shade intolerant trees like Schima wallichii and Duabanga sonnertioides.

Table 3.4

Analysis of "bamboo (Dendrocalamus hamiltonii) population in successional communities developed after slash and burn agriculture (Jhum).

	Age of fallow (years)				
	5	10	15	20	50
Frequency $\langle fo$	25	90	96	100	40
Average density (shoots/ 100m <sup>2</sup> )	8	38	45	56	15
Dead shoots ( $\langle *$ )	0	3	8	15	58
New shoots (%)	25	30	42	32	9
Average circumference of shoot (cm)	10	21	30	35	45

shade tolerant species like Shorea robusta, Vitex  
perdundum, Caetanopsis indjca, Garcinia cowa, Eugenia  
communis and Prunus aminata also become established but  
 none is able to achieve dominance in the community (Table 3.2).

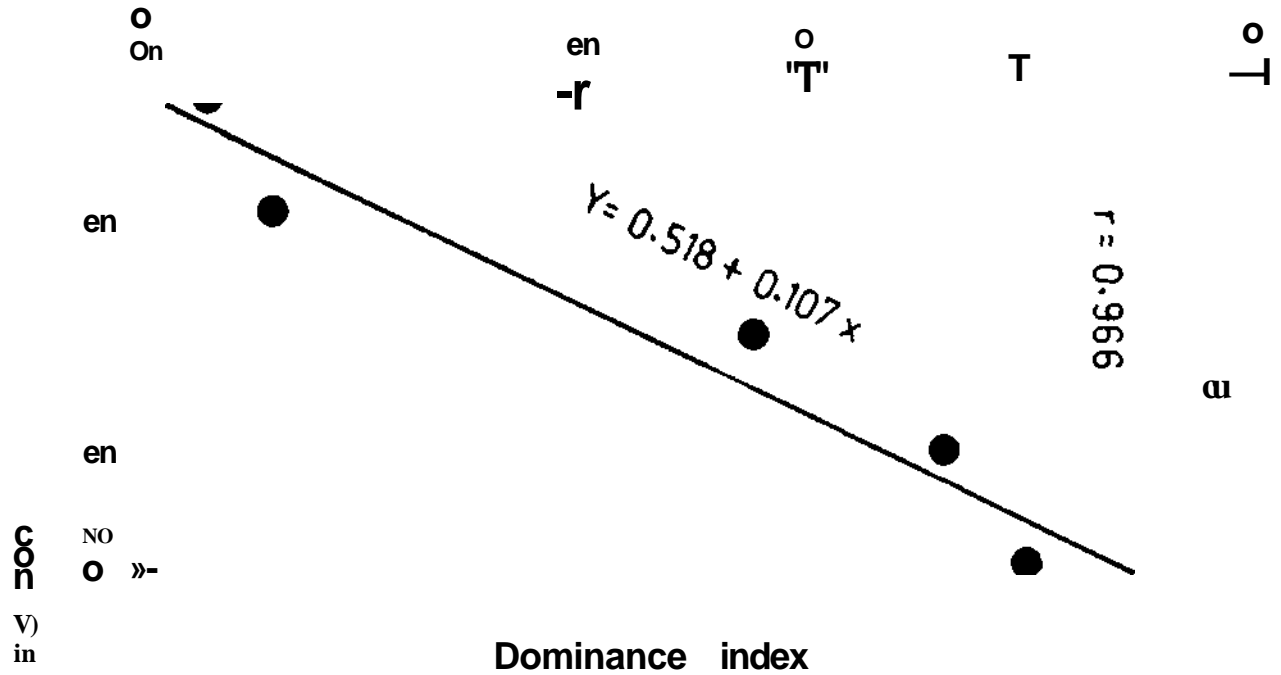
Species diversity was very low in early successional stages upto 5 years when the fallows were dominated by a few weedy colonizers, it increased sharply in older fallows with a significant positive correlation ( $r = 0.966$ ) upto a 20 year fallow (Fig. 3.1 a). In a 50 year fallow also the diversity was high with a high value of 2.58 though the increase in diversity beyond 20 years was not proportionate with the age of the fallow. Conversely dominance was maximum in the early phases of succession and decreased sharply with the age of the fallow. A significant negative correlation ( $r = 0.997$ ) between dominance and the age of the fallow was evident upto 20 years (Fig. 3.1b). Though the dominance index was lower in a 50 year fallow (0.115) compared to that of a 20 year one, the decrease in dominance was again not proportionate to the age of the fallow.

#### Litter production?

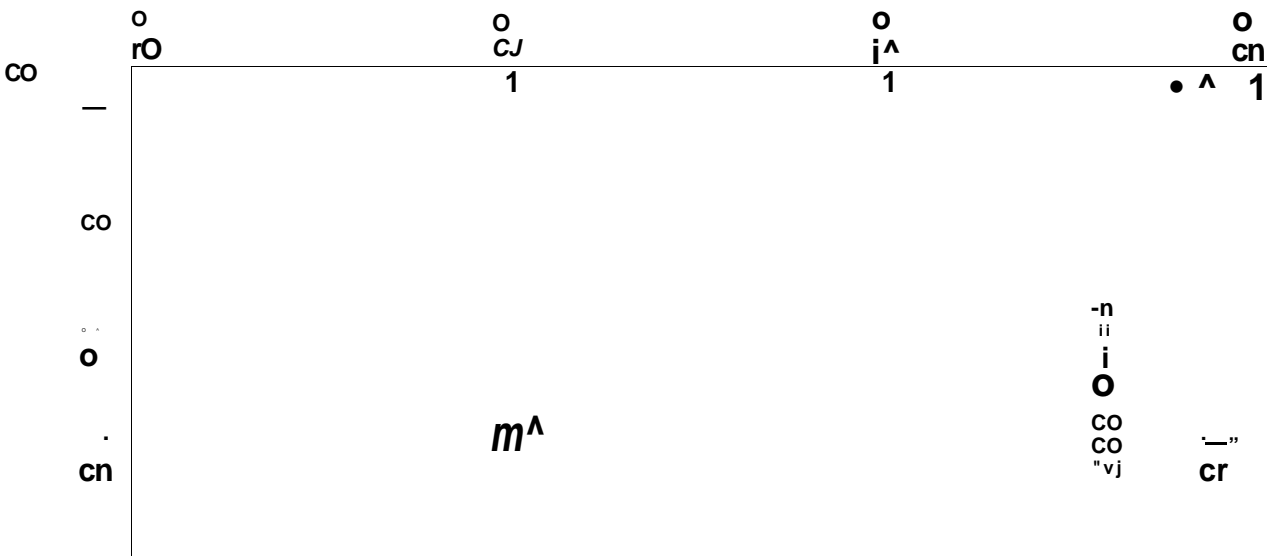
Total production of litter in successional communities is significantly related with their age and

Pig. 3.1. Species diversity (a) and dominance (to)  
related to the successional age of the  
fallows developed after 3hum cultivation.

### Diversity index



### Dominance index



standing biomass (Fig. 3.2a,b). Litter production increased with age and reached a maximum of 9.698 m.tons/ha/yr in a 20 year stand.

Maximum litter was contributed by bamboo (Dendrocalamus hamiltonii). which increased with the age of the fallow and formed nearly 50% of the total annual collection in 10,15 and 20 year old vegetation. Eupatorium odoratum contributed a major proportion (73%) in a 5 year fallow. Litter from dicot trees collectively, increased with successional age and accounted nearly 43-46% of the total in 10,15 and 20 year fallows (Table 3.5).

Leaves accounted for nearly 70-87% of total litterfall in 5 to 20 year fallows whereas in a 1 year fallow it was the only form of litterfall. Bamboo twigs formed an important component of litter biomass in a 10 year fallow and its proportion gradually increased upto 20 years. Litterfall through dicot twigs was maximum in a 5 year fallow (29.1%) and was mainly derived from Eupatorium odoratum which is eliminated due to death of its -population beyond this stage (Table 3.5).

i great seasonality of litterfall- was observed particularly in 5,10 and 20 year fallows. No litterfall occurred in the early part of the monsoon (June-July).

Pig. 3.2. Litter production as a function of successional age (a) and standing biomass (b) in fallows ( 0 , 1 year; 0 , 5 year\* • , 10 year; Q , 15 year} A » 20 year of age) developed after 3hum cultivation.

Litter production (m.ton/ha/yr. )

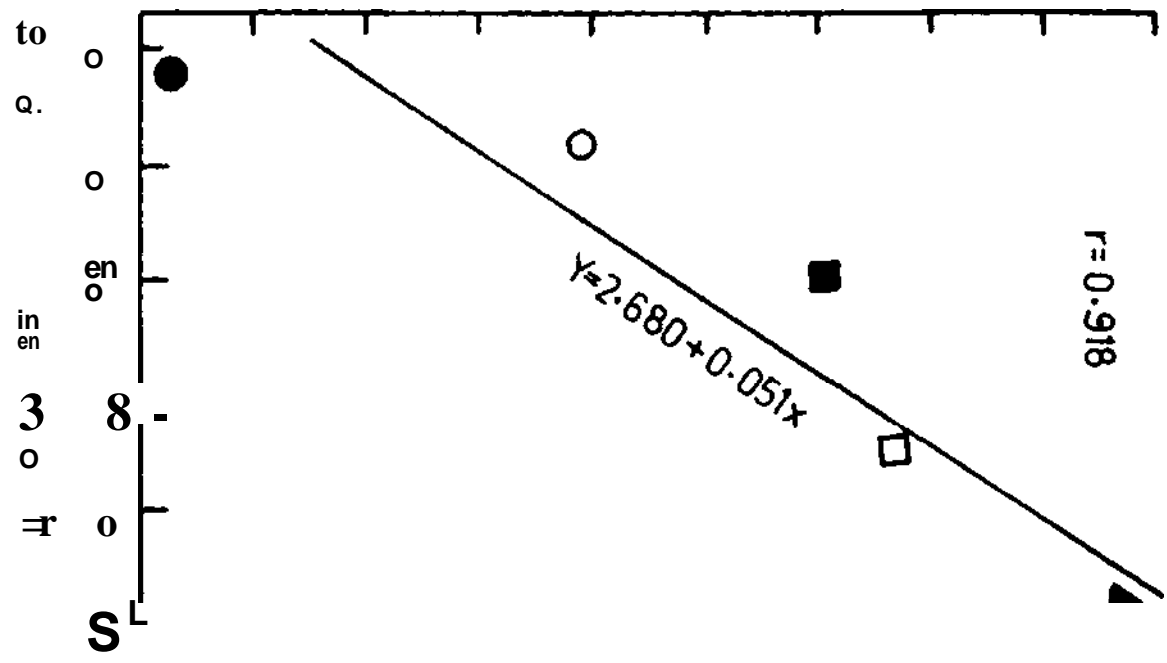
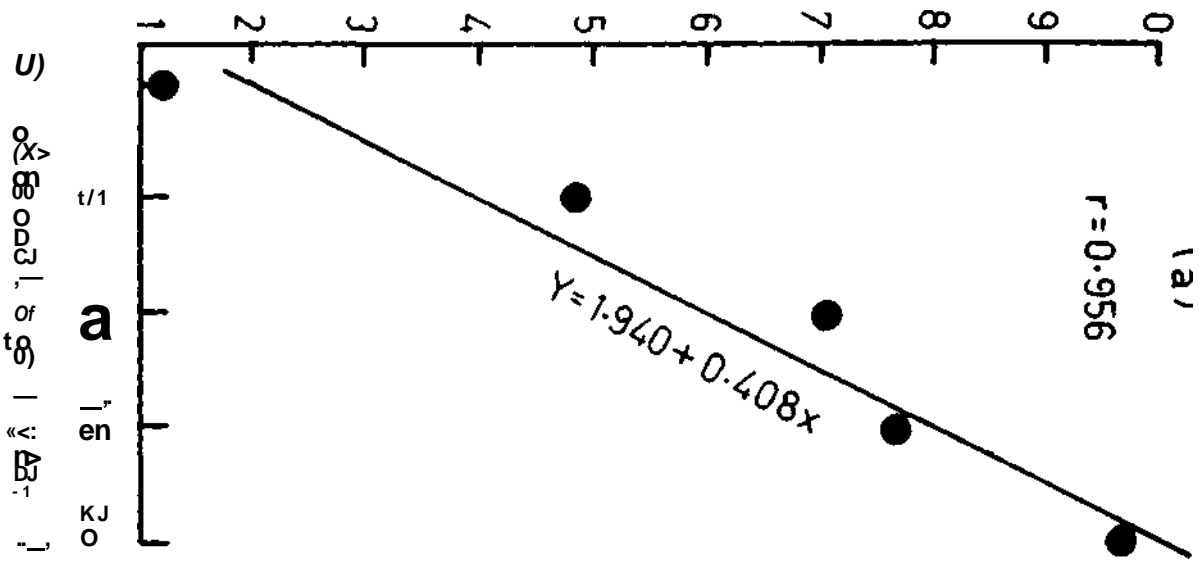


Table 3.5  
 Annual litter fall ( $\text{g/m}^{\text{P}}$ ) in successional communities developed  
 after slash and burn agriculture (Jhum) (\$ values of the total  
 litter are shown in parentheses).

Litter category	Successional age (years)				
	1	5	10	15	20
Dicot leaves	80.2 (68.2\$)	214.1 (43.7\$)	306.1 (43.2\$)	353.6 (46.0\$)	414.8 (42.7\$)
Bamboo leaves		12.0 (2.4\$)	316.5 (44.7\$)	322.6 (41.9\$)	428.6 (44.2\$)
Grass leaves	37.5 (31.1\$)	120.3 (24.5\$)			
Dicot twigs		142.3 (29.1\$)	49.5 (7.0\$)	28.5 (3.7\$)	33.9 (3.5<)
Bamboo twigs			35.5 (5.0\$)	63.7 (8.3\$)	92.3 (9.5\$)
To+<d:	117.7	489.3	707.6	768.5	969.8

litterfall starting during the latter part of the monsoon in August exhibited two peaks, a smaller one during October-January and a larger peak during February-April. One year fallow did not show such a marked seasonality though litterfall was maximum in February-March (Fig. 3.3).

#### Biomass;

The standing biomass in the successional communities increased linearly with the age of the fallows and attained a maximum of 147.59 m.ton/ha (Fig. 3.4a) in a 20 year old fallow. Herbs accounted for 100% of the total biomass in a 1 year fallow and 63.6% in a 5 year fallow; in subsequent years their contribution declined sharply. The biomass contribution by Dendrocalamus hamiltonii increased with the age of the fallow and reached its maximum in 20 years. A similar trend was noticed for shrubs and dicot trees (Table 3.6).

In older fallows of 10-20 years, the biomass contribution through the main stem and branches represented 93 to 95% of the total and leaf biomass represented only 5 to 7 %. In a 1 and 5 year fallows the biomass contribution by leaves represented as much as 17% and 19% resp. (Table 3.6).

\*1\* 3,3> Monthly pattern of litter fall •

fig- 3-3

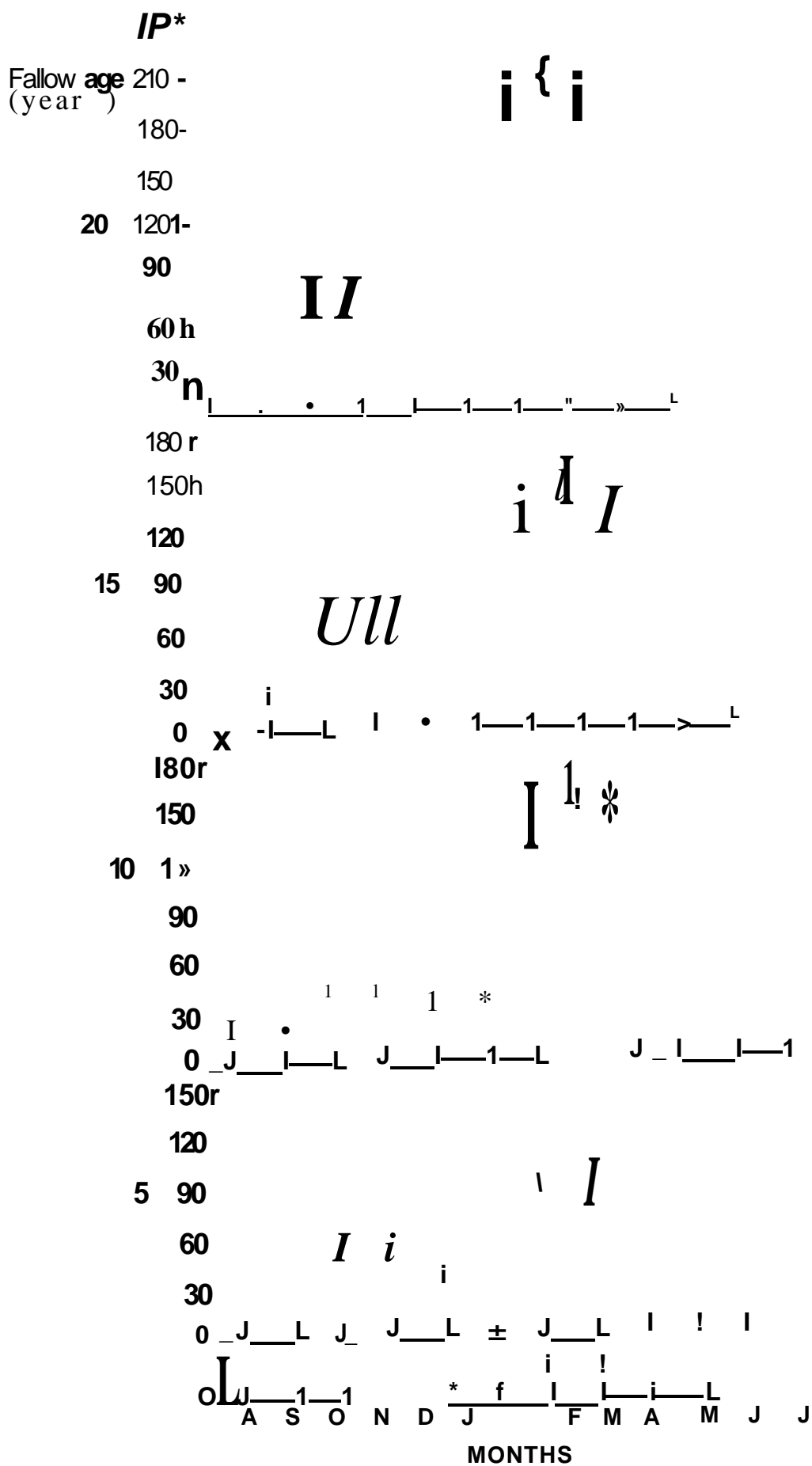


Fig. 3.4. Relationship between standing biomass (a) or net community productivity (b) and successional age of the fallows developed after jhum cultivation.

Standing biomass (m.ton/ha )

F

C/I  
T

o

CD  
o

T  
o

T  
o

"I

en

^

&

^

+Z \$6? X

=  
o  
to  
CO

DI

en

o

5'

Net community productivity (m.ton/ha/yr.)

5

6

8

10

12

14

16

18

20

o

1

5

10

15

20

r=0.973

$$Y = 5.386 + 0.697X$$

(b)

Table 3.6

Changes in standing biomass (m ton/ha) in different compartments and different categories of species in successional communities developed after slash and burn agriculture (Jhum).

Category-	Successional age (years)				
	1	5	10	15	20
Bamboo Total:		2.318 (9.9\$)	32.248 (56.1? \$)	59.147 (56.9\$)	74.971 (50.896)
Main Stem		1.995	26.581	50.970	61.831
Branches		0.236	4.411	5.365	9.654
Leaves		0.087	1.256	2.812	3.486
Dicot shrubs & Trees Total:		6.122 (26.47£)	25.003 (43.5^)	44.620 (42.9'*)	72.554 (49.2^)
Main stem		5.980	17.948	31.733	53.290
Branches			4.770	10.037	15.236
leaves		0.172	2.285	2.850	4.028
Herbs Total:	4.808 (±00\$)	14.766 (63.6^)	0.155 (0.3#)	0.073 (0.2*)	0.065 (negligible)
Main stem					
Branches	3.978	10.560	0.090	0.045	0.040
leaves	0.830	4.206	0.065	0.028	0.025
Total standing biomass (m,ton/ha)	4.808	23.206	57.406	103.840	147.590

; Petol(Wri\*Y- VALUUL O\ eacL Ced'teq-t>r u, \A /5110(A)'''''''' inA looAJI/vi tKJU«^

An increasing trend was observed in the rate of accumulation of aboveground biomass through successional stages, it showed similar rates in 1 and 5 year regrowth vegetation, increased about 2-fold beyond 5 years and finally attained maximum yearly rate of 8.95 m.ton/ha upto 15 years with a decline between 15 and 20 years. Litterfall and NPP both increased with increase in age of the fallow upto 20 years but with sharp rise in productivity upto 10 years of regrowth (Table 3.7). A significant positive correlation ( $r = 0.973$ ) existed between age of the fallow and EPP (Fig. 3.4b).

The regression between NPP and diversity/dominance of the communities showed highly significant relationships. Thus an increase in species diversity with a corresponding decrease in dominance resulted in increase in FPP (Fig. 3.5a,b).

#### DISCUSSION

In jhum cultivation, when a forest is converted to cultivable land, not only is its original vegetation destroyed but the site is subject to continuing perturbations due to fire, introduction of a variety of crops, successive weeding and diaturoance to soil at the time of

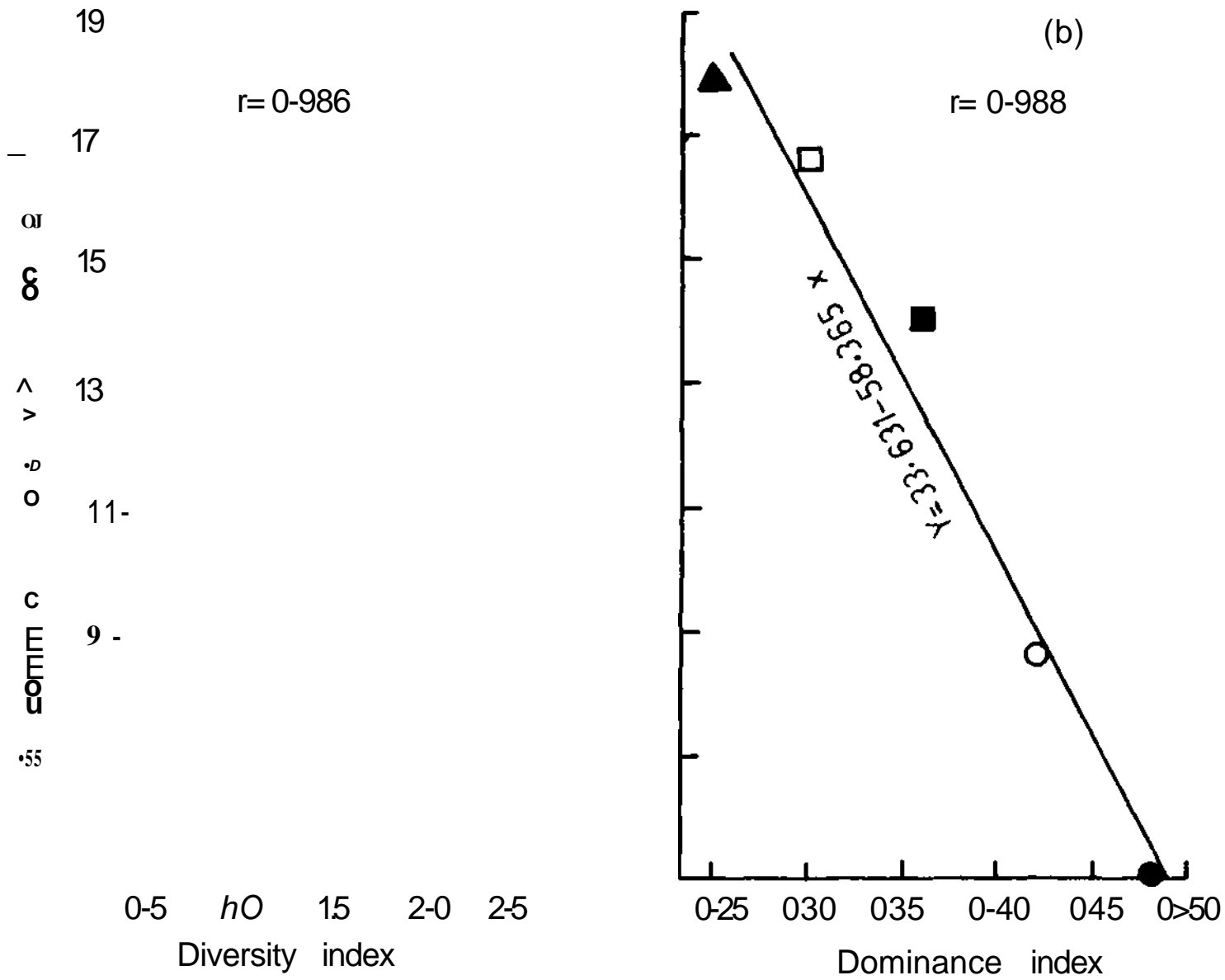
Table 3.7

Changes in rates of accumulation of biomass, litter fall and net primary productivity in successional communities developed after slash and burn agriculture (Jhum)

	Successional age (years)				
	1	5	10	15	20
Accumulation in bole and branches (A) (m.ton/ha/yr)	3.978	3.750	7.010	8.950	8.300
Release as litter fall (B) (m.ton/ha/yr)	1.177	4.893	7.076	7.685	9.698
Net primary productivity (A&B) (m.ton/ha/yr)	5.155	8.643	14.036	16.635	17.998
Biomass accumulation ratio (standing biomass/initial biomass)	0.9	2.7	4.1	6.2	8.2

Fig. 3.5. Relationship between net community productivity and species diversity (a) or dominance (b) in successional fallows ( • , 1 year; O » 5 year; *m* , 10 year; Q , 15 year; *M* <sub>f</sub> 20 year of age) developed after 3 hum cultivation.

fig 3.5



harvesting of which is a progressive reduction in the pool of the species present in the original ecosystem. Thus the early successional seres are dominated often by a few species and the number increases gradually as a community develops (Ross, 1954; Oosting, 1956; Odum, 1969).

A variety of reproductive and growth strategies are adopted by successional species among which stump, root and rhizome sprouts and invasion through seeds are common. The relative importance of different species and their strategies could vary depending upon the length of the jhum cycle, species composition and structure of the ecosystem prior to cutting, degree of disturbance to the soil during cropping, available seed source, etc. These are aspects which need to be investigated. In sites under a 5 year jhum cycle with cropping for one year only, as in the present case, Eupatorium odoratum is a significant component of early communities. Heavy production of seeds which are light and wind transported help them to succeed as an early colonizer. The importance of heavy seed production for early species was stressed by Hayashi & Numata (1968) and Raynal & Bazzaz (1973) while Salisbury (1942) emphasized that species with light, highly mobile seeds often invade highly disturbed situations while species with heavier seeds, often animal

disseminated, usually enter the ecosystem at a later stage of development. Imoerata cvlindrica which also is an early colonizer, on the other hand has fire resistant underground rhizomes which are difficult to eradicate during cultivation. This strategy alongwith production of light wind dispersed seeds under constant disturbance (Saxena & Ramakrishnan, unpublished) contribute to their success. These early species which adopt an exploitive strategy (Harper & White, 1974; Grime, 1974; Marks, 197k) are able to attain dominance in abandoned fields that are temporarily enriched with nutrients, water and radiant energy.

During the first 10 years, the dominance passes rapidly from weedy colonizers to bamboo (Dendrocalamus hamiltonii) and other shade intolerant dicot tree species. As discussed elsewhere, Dendrocalamus hamiltonii has an important conservational role to play as it is a heavy accumulator of potassium (Toky & Ramakrishnan, unpublished). Within 50 years shade tolerant species dominate the community. The shift in dominance is quicker in the early phases of succession and becomes slower in the later phases of succession (Richards, 1952; Marks, 1974). The rewards of dominance are great, since dominance implies a proportionately larger control over biogeochemical and hydrologic

pathways of the ecosystem, conservation of nutrients and their distribution in various compartments of the ecosystem.

Litter production:

The values of litter production in successional communities in the present study fall within the published range of values recorded for mature and secondary forests of tropics and sub-tropics. Mitchell (cited by Bray & Gorham, 1964) reported values ranging from 8.3 to 14.4 ton/ha/yr for three secondary forests and 5.5 to 7.2 ton/ha/yr for three mature forests in Malaya. For strongly Amazonian seasonal forests Klinge & Bodrigues (1968) reported an average value of 7.3 ton/ha/yr. Ewel (1976) estimated values of 4.6 to 10.0 ton/ha for 1 to 14 years successional community and 9.0 ton/ha for mature forest in Guatemala. Higher values for mature forests reported are 12.3 to 15.3 ton/ha. (Laudelot & Meyer, 1954) in Zaire and 7.2 to 13.4 ton/ha (Bernhard, 1970) in Ivory Coast.,

Relatively high values of litter production in secondary successional communities in the present studies as compared to a comparatively older one of 50 years age (5.5 ton/ha/yr) in the same area as reported by Singh & Ramakrishnan (unpublished) is due to the fast developing vegetation during the early successional stages and the

consequent rapid turn over of biomass. In early jhum fallows, bamboo (Dendrocalamus hamiltonii) and a number of early dicot tree species are deciduous in nature compared to the species in an older forest. Since a successional community undergoes change in species composition; often entire individuals may contribute to litter production. These factors might combine to result in an 'overshoot' of litter production during the early successional phases (Ewel, 1976).

*The* distribution of litterfall was markedly seasonal, with a peak fall during dry periods of the year, a pattern also observed by Klinge & Rodrigues (1968) in an Amazonian lowland forest. A rather different seasonal trend in a tropical rain forest where peak litterfall coincided with the advent of heavy rains at end of dry season was reported by Edward (1977).

#### Biomass:

A sharp increase in the aboveground biomass with age upto 20 years was noted and the present values are comparable to the range given for many tropical and sub-tropical forests. The values reported are 46.09 to 121.68 for 6-8 years in S. Nigeria and Belgium Congo (Nye & Greenland, 1960)} 24.36 to 42.45 for 2-6 years and 370.53

for mature forest in Darien, Pan (Gulley et, al, 1969); and 8.36 to 72.40 m.ton/ha for 1-9 years in Izabal, Guate (Snedaker, 1970),

The secondary forest ecosystems show a great tendency to accumulate biomass in the early stages of succession as seen from the present study where the standing crop biomass increased from 23.206 m.ton/ha in a 5 year fallow to 147.49 m.tons/ha in a 20 years forest. However, between 20-50 years, there was no increase at all in the standing biomass of the community. It may be noted that the biomass values calculated are on the basis of 11 important tree species and all the shrubs and herbs in the community. Even if all the minor tree species are taken into consideration, the total biomass value is not likely to be too high (Singh & Eamakrishnan, unpublished). This may be due to replacement of fast growing shade intolerant species by slow growing shade tolerant ones in later stages of succession.

According to Lugo (1973) maximum biomass value for tropical forests is approached in about 30 years at a level of 250 m.ton/ha, whereas in a temperate forest in northern hardwoods of USA, after clear-cut the living biomass rises to a peak of 490 m.ton/ha in about 170 years only (Bormann & Likens, 1979). While according to Marglef (1968), Odum (1969), Whittaker & Woodwell (1972) a steady-state for biomass immediately follows the attainment of the peak during succession, according to Bormann & Likens (1979) this is

reached only after a transition period of more than 100 years. In any case, a steady-state for biomass is reached in a shorter time in tropics whereas it takes a much longer time under temperate forests.

The rate of accumulation of biomass increased upto 15 years of regrowth and declined in a 20 year fallow. This is possible due to faster growth rate of bamboo (Dendrocalamus faamiltonii) and other shade intolerant dicot tree species. Such a faster rate of development of the community in the early successional stages was also reported by others, Snedaker (1970) reported maximum rate of increase of biomass of 19.23 m.ton/ha/yr in Izabal, Guete upto 7-8 years with a subsequent decline, Bartholomew, Meyer & laudelot (1953) showed a maximum rate of 26.6 m.ton/ha/yr in a new forest of Musanga cecropioides upto a period of 5-8 years. However, growth rate also depends upon the type of vegetation established at the early phase of succession, nutrient status of the soil and other environmental conditions.

#### Productivity:

The community showed increasing productivity upto 20 years, which is largely based upon the growth response of exploitive species utilizing resources available by destruction of biomass component present before clearing, accelerated decomposition of floor organic matter and favourable conditions of radiant energy. The rapid increase in productivity after 5 years may be due to a shift in dominance

from weedy species utilizing inefficient exploitive growth strategy to tree species utilizing more efficient conservative strategy; bamboo with its deep and extensive rhizome systems, a large canopy and efficient uptake and conservation of nutrients like potassium would be an example of such a shift. Shade intolerant fast growing tree species exhibit rapid growth at this stage.

The value calculated for NPP in the present study, fall in the range of values reported for secondary and mature forests. Jordan (1971) reported values of 5.4 m.ton/ha/yr for a 3 year old successional forest and 10.3 m.ton/ha/yr for old Rain forests in Puerto Rico. Tropical forests as a whole, with a mean annual WPP of 21.6 m.ton/ha, exceeds temperate forests, averging 13.0 m.ton/ha and boreal forests averging 8.0 m.ton/ha. In an oak-pine forest in New York where productivity was measured during succession (Holt & Woodwell, quoted by tfhittaker, 1975), it was shown that net productivity increases to a fairly stable level in the meadow stage of succession and then increases more steeply through the shrub and young tree stage to 12 m.ton/ha/yr in the oak-pine forest of 44-55 years age. This is in agreement with the present results. However, Mellinger & Mc Broughton, (1975) showed a contrasting trend where over a

30 year period during succession in old fields in Central New York, there was a decrease in average net productivity.

There has been much discussion on the diversity and its relationship with successional stage and in turn to productivity and stability. Odum (1969) and Woodwell & Saith (.1969) are of the view "that species diversity generates functional stability. On theoretical consideration<sup>-5</sup>, May (1973) has shown that increasing diversity destabilizes the interacting systems. However, McNaughton (1967) and Mellinger & McNaughton (1975) have shown that succession was accompanied by increase\*\* biological diversity and reduced dominance. On the basis of perturbation studies they have positively related diversity with stability. This has been contradicted by Singh & Misra (1969) who suggested for serai grasslands that species diversity increases production efficiency of the ecosystem while decreasing dominance makes the system more stable though less efficient production. Our own studies indicate, however, that diversity increases with progress of succession with a consequent decrease in dominance. This is accompanied by increase in net community productivity which is steep upto 20 years and gradual beyond this stage.

## SUMMARY

The secondary successional pattern of plant communities subsequent to shifting agriculture (locally known as •Jhum<sup>1</sup>) upto 50 years fallow and the biomass, productivity and litterfall patterns during succession upto a 20 year fallow period were studied. The early weedy colonizers vary depending upon the type of vegetation that is slash&Land burnt and the seed source available in the soil depending upon weeding practices at the time of agriculture. Dendrocalamus hamiltonii, a bamboo species, dominates the fallow between 10-20 years which is replaced by more shade tolerant dicot trees. Succession was accompanied by increased species diversity, reduced dominance and increased net primary productivity. Total inventory of aboveground biomass increased linearly with age and attained a maximum value of 147.59 m.ton/ha in a 20 year fallow. The rate of accumulation of biomass showed increasing pattern upto 15 years of secondary growth with the highest value of 8.95 m. ton/ha/yr and declined in a 20 year fallow. The net primary productivity increased linearly with the age of the fallow reaching a maximum of 17.99 m.ton/ha/yr. Litterfall showed a significant positive correlation with age of the fallow and total standing biomass of the fallow, reaching a maximum of 9.69 m.ton/ha/yr collected in a 20 year stand.

CHAPTER 4

SOIL FERTILITY STATUS OF HILL AGRO-  
ECOSYSTEMS AND RECOVERY PATTERN AFTER  
SLASH AND BURN AGRICULTURE (JHUM) IN  
NORTH-EASTERN INDIA.

SOIL NUTRIENT STATUS OF HILL AGRO-ECOSYSTEMS  
AND RECOVERY PATTERN AFTER SLASH AND **BURN**  
AGRICULTURE (JHUM) IN NORTH-EASTERN INDIA

INTRODUCTION

Shifting agriculture in the north-eastern India (locally called \*Jhum\*) involves clearing of the forest, burning of dried biomass, mixed cropping for a period of 1 or sometimes 2 years, and then reverting the land back to its natural vegetation so as to restore soil chemical fertility and to improve its physical properties. The long term success of this practice of agriculture depends upon the recovery and maintenance of soil fertility. If the nutrients lost or displaced during the short period of cultivation are approximately balanced by those replaced during the fallow period, the system could continue indefinitely. The maintenance of soil fertility in hot, humid and high rainfall areas is a serious problem and is more severe in situations when the cycle becomes short, due to poor recovery of soil fertility and increased intensity of weed competition. This in turn results in reduced crop yield under short jhum cycles (**Toky & Ramakrishnan**, unpublished).

This study on 'jhum' was done at Burnihat which is located in the Khasi hills of Meghalaya at 26.0° N and 91.5° E. Here shifting cultivation ('jhum') is practised by one of the tribes of Meghalaya namely the 'Garos'. The climate at Burnihat is hot and humid with an average rainfall of 220 cm. Climate could be divided into three distinct seasons. The dry and windy summer runs from mid-February to May with average maximum temperature of 33°C and minimum temperature of 9°C. The rainy season extends from May to October. This is a warm period with high humidity. The mild winter with an average maximum temperature of 25°C and an average minimum temperature of 5°C extends from November to mid-February. This period is practically rainless except for a few winter showers. The angle of the slope varies from 20° to 40°. The soil is of lateritic origin.

The present study deals with the changes in soil nutrient status under three different jhum cycles of 30, 10 and 5 years and its decline due to various losses through run-off and leaching. It also deals with the recovery of the soil fertility as a forested cover develops after the land is left as fallow after jhum cultivation.

## METHODS OF STUDY

For study of chemical characteristics of the soil, three deforested sites under 30, 10 or 5 year jhum cycles were selected. While selecting the different sites, care was taken to ensure similar slope conditions ( $32^\circ$  average), exposure and soil types. In all the three sites soil samples were taken five times during one year of study to "represent soil conditions : (i) after cutting but just before burning the slash (in March), (ii) immediately after burning (in March), (iii) during early monsoon (in May), (iv) during the mid-monsoon (in June) and (v) after one year of cropping (in April of the following year). Sites representing forested fallows were 1,5,10,15 and 50 years of age. Soil sampling in these fallows was done in the month of March. Sampling in each site was based on 10 soil collections to represent the entire topography of the slope. These samples were thoroughly mixed into a composite one to represent that site. Soil sampling in all the study sites was done through a depth of 0-40 cm. separately at intervals of 0-7, 7-14, 14-28 and 28-40 cm.

pH was determined in a soil-water suspension of 1:5 ratio using a pH meter. Total nitrogen, carbon,  $\text{NO}_2\text{-N}$ ,



P<sub>04</sub>-P, pH and exchangeable calcium, magnesium and potassium were analysed following standard methods (Allen, 1974). Thus, soil carbon was determined by Walkey-Black method and total nitrogen by Kjeldahl method. Magnesium and calcium were analysed by EDTA titration method while potassium was estimated by flame emission method after extracting the exchangeable cations with 1N Ammonium acetate at pH 7. IrOg-N  
foe.

8 was estimated by phenol-di-sulphonic acid method and P<sub>04</sub>-P was estimated by molybdenum blue method, both colorimetrically. The soil bulk density was used for subsequent conversion of analytical data to field weight per unit area.

## BESUITS

### Carbon

Before burning the slash, percentage carbon in the surface soil was higher under 30 and 10 year jhum cycle sites (2.49% and 2.65% resp.) compared to that under a 5 year cycle (1.82%). Immediately after burning, there was significant reduction in the carbon content in the surface soil and this was more pronounced in sites with 10 and 30 year cycles compared to the 5 year one. This trend for reduction in carbon continued upto a period of 3 months in 10 and 30 year jhum cycle sites and for a period of 1 month only in the

site of 5 year cycle. Beyond this period, carbon content in the surface soil showed an increasing trend. The changes in the carbon content in the lower layers were not as pronounced as in the surface layer. It is also interesting to note that in general carbon content in all the different layers of the soil profile was maximum under a 10 year jhum cycle and was the least under a 5 year cycle

Carbon content ( $\text{kg/m}^2$ ) for the entire soil profile upto a depth of 40 cm showed that there was a sharp decrease in the quantity immediately after the burn under 10 and 30 year cycles only. Under a 5 year cycle the burn did not affect the amount of carbon in the soil. Decline in carbon content continued in all the sites upto 3 months after the burn and was most pronounced under 10 year cycle. Thus the site under a 10 year cycle lost 17.3% of carbon out of the original  $7.979 \text{ kg/m}^2$  under a 5 year cycle. After 12 months, recovery of carbon was noted in all the sites. As mentioned earlier the site under 10 year jhum cycle had maximum carbon content during the entire 1 year period. The net loss from the three sites after a year of cropping was to the extent of  $1.787 \text{ kg/m}^2$  under 10 year cycle,  $1.274 \text{ kg/m}^2$  under 30

Table 4.1

Changes in carbon (#) through the soil profile after burn and during  
 reforestation in sites under different jkua cycles

Sampling time (days)	Soil depth (cm)	Jkua cycle (years)											
		30				10				5			
		0-7	7-14	14-28	28-46	0-7	7-14	14-28	28-40	0-7	7-14'	14-88	28-40
<j>1		2.49	1.74	1.35	1.09	2.65	2.14	1.68	1.43	1.82	1.43	1.21	0.94
1		2.16	1.60	1.27	1.10	2.20	1.92	1.60	1.38	1.74	1.51	1.18	1.03
30		2.12	1.52	1.30	1.02	2.03	1.80	1.52	1.33	1.62	1.40	1.10	0.90
90		2.03	1.50	1.35	0.92	1.90	1.75	1.40	1.34	1.68	1.45	1.03	0.82
365		2.12	1.63	1.25	1.01	2.08	1.80	1.36	1.37	1.78	1.50	1.15	0.85

year cycle and 0.327 kg/m under a 5 year cycle (Fig. *u.t* ).

In all the forested fallows, percentage carbon declined with increase in depth throughout the profile, it also declined with age of the fallow upto 5 years, with a maximum level recorded in a 0 year fallow (after one year of cultivation). In a 10 year fallow, the carbon level improved markedly and was only slightly altered in a 50 year fallow (Table tf.1). The total carbon of 9.750 kg/m<sup>2</sup> upto a depth of 40 cm in a 0 year fallow declined markedly after one year of revegetation and subsequently improved upto a 10 year fallow and declined markedly in a 15 year fallow (this is probably related to ground fire, discussed below) and again improved slightly in a 50 year fallow but stabilized at a lower level than that of a 10 year one (Fig. ^.StA).

#### Total nitrogen

Before the burn, total nitrogen concentration in the upper layers of the soil under 30 and 10 year jhum cycles was almost equal and was much higher than at the site under 5 year cycle. Under 30 and 10 year cycles, nitrogen concentration in the surface layers declined sharply after the burn and the decline was less marked in

Fig. 4.1. Changes in total quantity of carbon within a soil column of 40 cm after burn and during cropping in sites under 30 (A), 10 (B) and 5 (C) year jhum cycles.

Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.

fig. 4.1

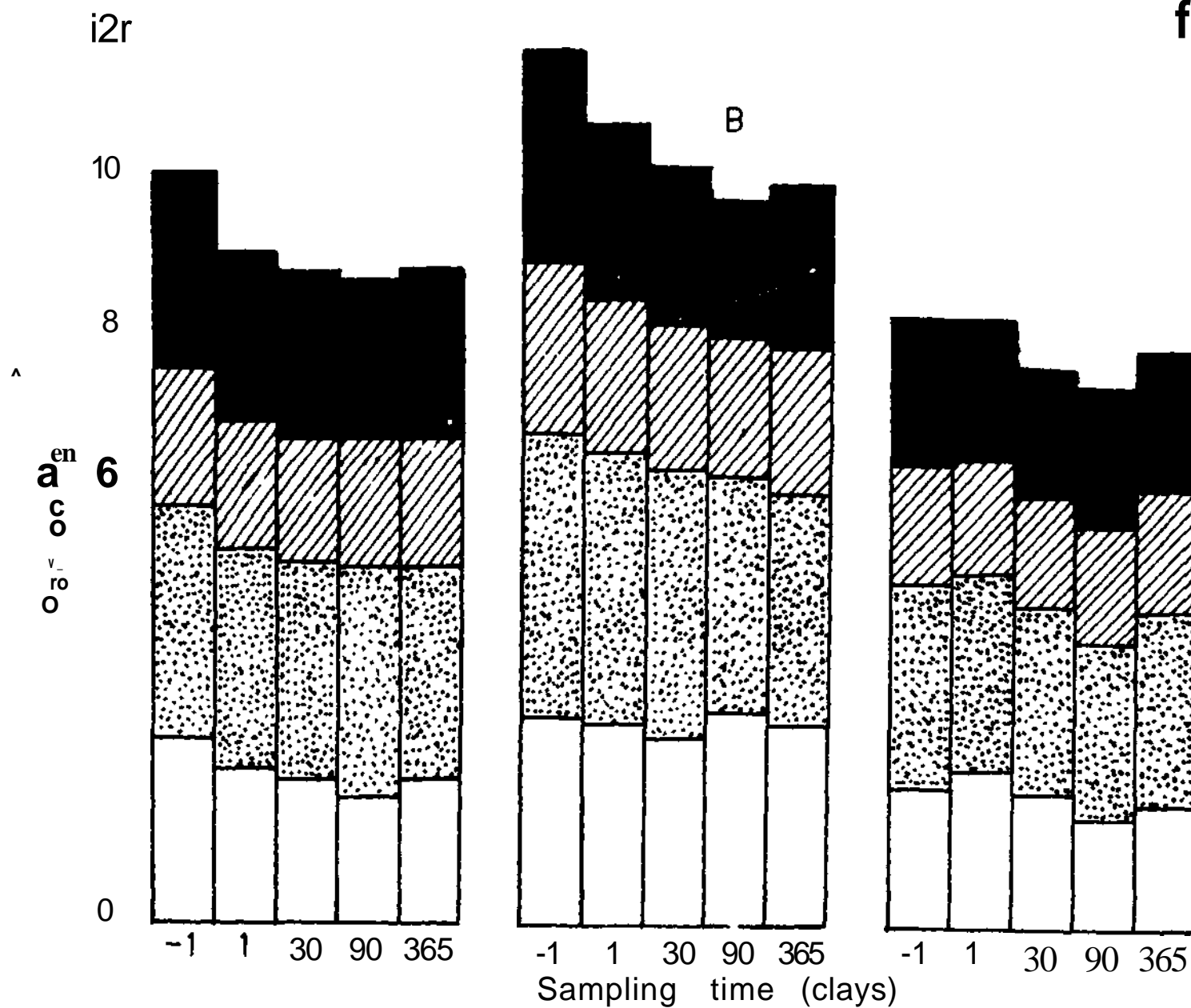
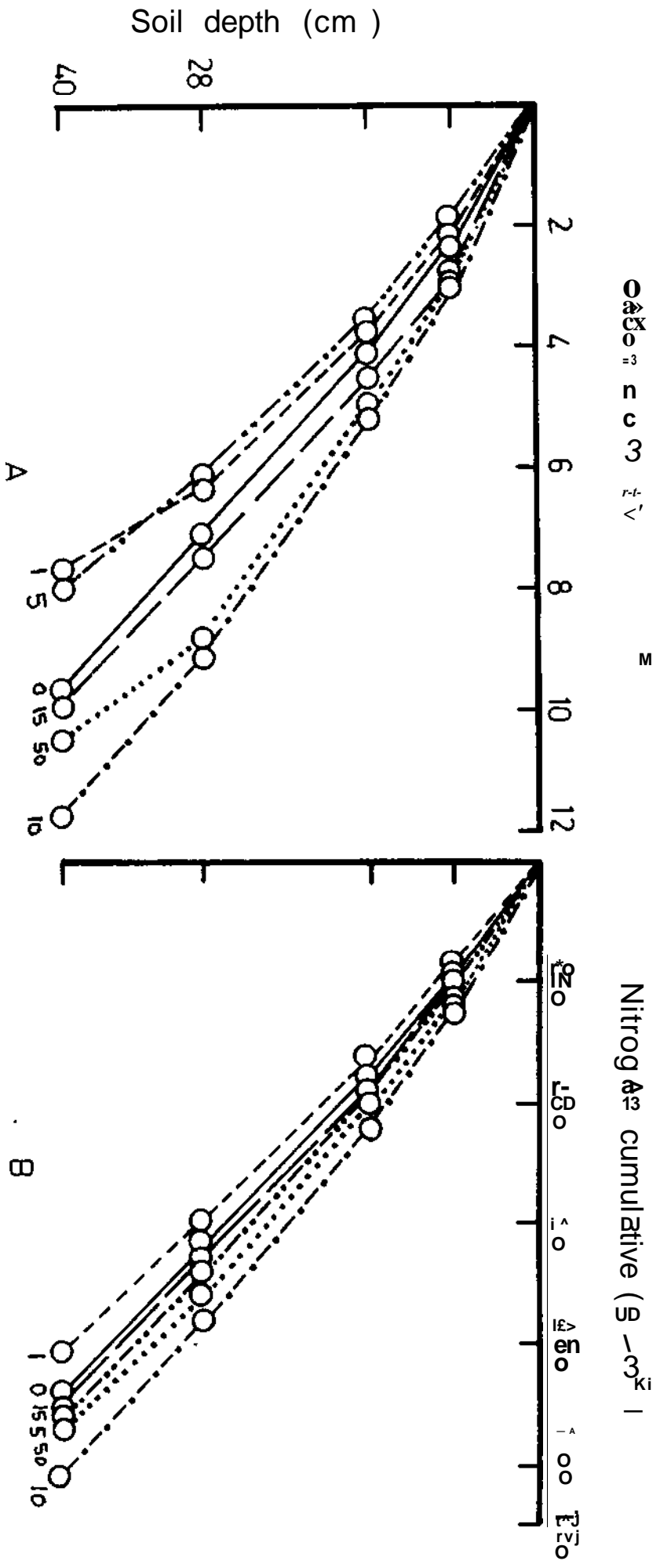


Table H.L

Changes in % carbon and nitrogen and C/N ratio in the soil profile under forested fallows of various ages.

Fallow (year)	<u>Soil depths upto 40 cm</u>											
	<u>0-7 cm</u>		<u>7-14 cm</u>				<u>14-28</u>		<u>28-40 cm</u>			
	C	C:N	C	C	C:N	C	C:N	C	C	C:N	C	
0	2.08	0.223	9.3	1.80	0.172	10.4	1.36	0.154	8.3	1.37	0.158	8.6
1	2.01	0.217	9.2	1.53	0.159	9.4	1.12	0.142	7.7	0.81	0.138	5.8
5	1.82	0.220	8.6	1.48	0.200	7.0	1.21	0.170	7.6	0.94	0.150	6.0
10	2.75	0.268	10.0	2.14	0.240	8.7	1.78	0.170	10.0	1.42	0.162	8.6
15	2.50	0.246	10.1	1.73	0.178	9.5	1.35	0.148	8.7	1.18	0.145	7.5
50	2.60	0.236	11.0	2.05	0.215	9.5	1.76	0.180	9.8	0.86	0.116	7.4

4.2. Changes in cumulative quantity of carbon  
 of  $1 \text{ T} \text{ f}^{11} \text{ J}^{\text{B}}$  Within a  $1 \text{ m}$  column  
 of 40 cm depth under fallows of various ages,  
 $r^{\circ} \sim Z \sim ? \gg \text{ }^{\circ} \text{ yea}^{\text{j}} \text{O} \text{---} \text{O}, \text{ i year.}$   
 O, 15 year; O..... $\sim \sim$ 0, 50 year.



the subsequent months. Further, the changes in nitrogen concentration over 1 year period were pronounced in the surface layer only. The decline in the concentration of nitrogen in the surface layer of soil (0-7 cm depth) after one year of cropping under a 30 year cycle was from an initial 0.270# to 0.204# whereas under a 5 year cycle it was just from 0.220# to 0.193# (Table 4/5).

o

Total nitrogen content (g/m<sup>3</sup>) over a depth of 40 cm was not significantly different before burn under 30 and 10 year Qhum cycles. However, in both these cases there was a sharp decline in total nitrogen during the first 3 months. A similar trend was also noted under a 5 year cycle though the initial pool of nitrogen before burn was significantly lower than under long 3hum cycles. Whilst the decline in nitrogen pool during the first 3 months was to the order of 15.5% of that original (before the burn) under a 30 year cycle, it was about 16.7% under a 10 year cycle and was to the extent of 10.5% in a site under 5 year cycle. The recovery of nitrogen between 3 and 12 months period was maximum under a 30 year cycle and least under a 5 year cycle; 10 year cycle was very close to the 30 year cycle in this respect (Fig. 4.3 ).

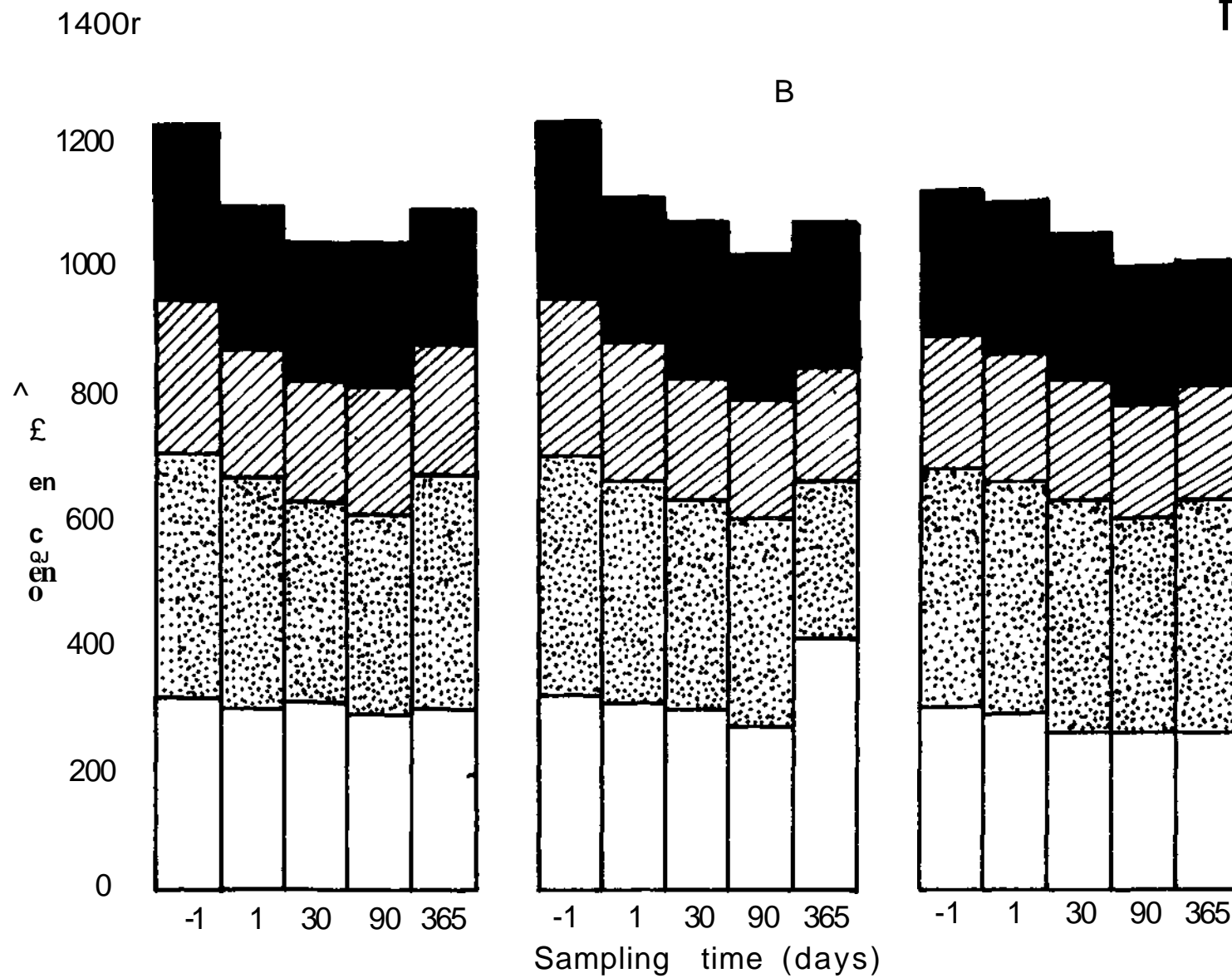
Table 4.3  
 Changes In nitrogen (N) through the soil profile after burn and during cropping in sites under different jhau cycles

Sampling time (days)	Soil depth (cm)	<i>J. hum.</i> cycle (years)											
		0-7	7-14	14-23	23-40	CP?	7-14	14-23	23-40	0-7	7-14	14-23	23-40
-1		0.270	0.226	0.176	0.160	0.268	0.240	0.170	0.162	0.220	0.200	0.170	0.150
1		0.223	0.136	0.163	0.152	0.223	0.210	0.158	0.155	0.230	0.191	0.166	0.144
30		0.214	0.178	0.146	0.152	0.236	0.135	0.148	0.150	0.220	0.178	0.160	0.140
90		0.220	0.190	0.142	0.148	0.220	0.185	0.140	0.145	0.212	0.170	0.153	0.130
365		0.204	0.196	0.170	0.150	0.223	0.172	0.154	0.158	0.193	0.171	0.156	0.140

Fig. 4.3. Changes in total quantity of nitrogen within a soil column of 40 cm depth after burn and during cropping in sites under 30 (A), 10 (B) and 5 (C) year jhum cycles.

Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.

fig-4.3



The nitrogen concentration in the different fallows showed a slight decline after 1 year of regrowth of natural vegetation as compared to that after a year of cropping (0 year fallow), but improved gradually in the fallows of 5 and 10 years of age and then tended to decline under a 15 year old fallow and slightly decreased or increased in a 50 year old fallow depending upon the soil depth. Nitrogen concentration in all the fallows decreased markedly with increase in depth of the soil (Table 4.1-)

Total nitrogen upto a depth of 40 cm declined in a 1 year fallow when compared with that immediately after cropping (0 year fallow). Subsequently nitrogen status improved and reached its maximum under a 10 year fallow and in 15 and 50 year fallows it stabilized at a lower level (Fig. 4.AB).

C/N ratio in all the fallows was higher in the surface layer of the soil and declined at lower depths. At a depth of 0-7 cm, this ratio reached its maximum in a 50 year fallow. At lower depths, however, this ratio had a maximum in a 10 year fallow and in older fallows of 15 and 50 years it slightly declined (Table 4.2.).

A comparison of Fig. 4.2A and Fig. 4.3B indicate that depletion of carbon and nitrogen through depth was in general more for the former than for the latter as indicated by the trend of the curves. It is also evident that depletion of these two at lower depths was maximum in a 1 year fallow compared to others.

#### Nitrate nitrogen

NO<sub>3</sub>-N concentration in the surface layer reached its peak after a month after the burn and declined markedly in subsequent months. Length of the cycle does not seem to have a marked effect on concentration. NO<sub>3</sub>-N concentration did not fluctuate much at lower depths (Fig. 4.4).

#### Available phosphorus

Immediately after the burn, available phosphorus showed only a slight increase, but it increased markedly after a month in all the three sites; this was more pronounced under a 30 year jhum cycle followed by the 10 year cycle. The concentration dropped significantly after 3 months of cropping. A slight increase after one year of cropping was noted only under 30 year jhum cycle. Available phosphorus showed decreasing trend with shortening of the jhum cycle at all times of sampling. At lower depths, no significant fluctuation was observed in all the three sites (Fig. 4.5).

**Table 4.4**  
**Changes in concentration (ng/100 g) of 10,-9 through the soil profile after burn and during cropping in sites under different J hum cycles**

Sampling time (days)	Soil depth («)	d <sup>TM</sup> L?	J hum cycle (years)											
			30			10			5					
			7-14	14-28	28-40	0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40	
-1		0*20	0.18	0.16	0.15	0.11	0.10	0.09	0.08	0.30	0.22	0.20	0.18	
1		0.21	0.17	0.16	0.15	0.10	0.10	0.08	0.08	0.2?	0.23	0.21	0.17	
30		0.55	0.25	0.17	0.14	0.37	0.18	0.10	0.08	0.49	0.26	0.21	0.17	
60		0.14	0.18	0.16	0.15	0.22	0.16	0.12	0.09	0.12	0.18	0.18	0.11	
90		0.21	0.18	0.18	0.14	0.25	0.17	0.12	0.10	0.18	0.22	0.20	0.14	

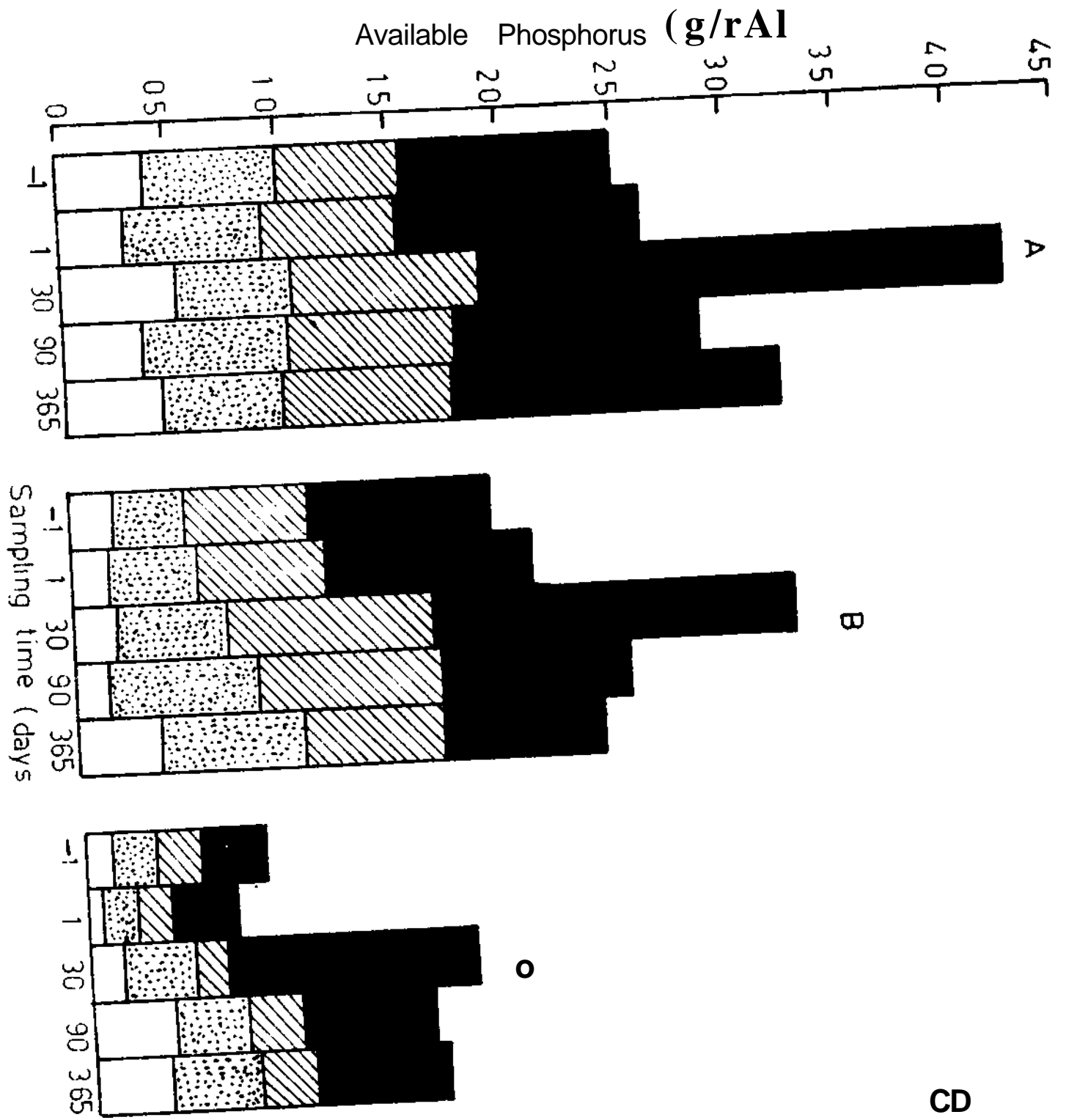
Table 4.5

Concentrations (mg/100 g) of available phosphorus after  
burn and during cropping in sites under different **Java** cycles

Sampling time (days)	Soil <sup>a</sup> (ea)	Java cycle (years)										
		<b>30</b>			<u>10</u>				<sup>s</sup>			
	M	7-14	14-28	28-46	SP?	7-13	14-28	28-46	(Z)	7-14	14-28	<b>Ii=4T</b>
<b>.1</b>	0.90	0.54	0.27	0.20	0.78	0.54	0.14	0.10	0.28	0.18	0.10	<b>0.0i</b>
<b>1</b>	0.14	0.58	0.28	0.16	0.88	0.54	0.18	0.10	0.30	0.14	0.06	<b>0.04</b>
30	2.24	0.80	0.22	0.30	1.54	0.90	0.22	0.11	1.08	0.14	0.14	0.98
<b>90</b>	1.04	0.64	0.32	0.20	0.82	0.78	0.30	0.08	0.56	0.24	0.14	0.20
365	1.28	0.72	0.30	0.24	0.68	0.62	0.28	0.20	0.44	0.24	0.18	0.18

Fig. 4.4. Changes in total quantity of available phosphorus within a soil column of 40 cm depth after burn and during cropping in sites under 30 (A), 10 (B) and 5 (C) year jhum cycles.

Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil\*



In general under all the forest regrowth phases, the soil maintained a comparatively low level of available phosphorus except in a 50 year fallow. In sites of 1 year and 5 year fallows, the available phosphorus concentration declined compared to that in a 0 year fallow (just after cultivation), and in older fallows, the concentration increased reaching the maximum in a 50 year fallow. These changes were marked in the surface layer of the soil only (Table 4.6).

Total available phosphorus declined in 1 and 5 year fallows and showed marked and steady improvement in 10, 15 and 50 year fallows. Depletion of available phosphorus with depth was also maximum in a 5 year fallow (Fig. 4.8A).

#### Exchangeable cations

Immediately after burning the slash, the concentration of all the cations in the surface soil increased considerably. This increase was more marked in the site under a 30 year cycle compared to a 10 year cycle and was least under a 5 year cycle, the exception to this trend being potassium which showed a similar increase under 10 year cycle as in a 30 year site. Initial concentration of all cations in the surface soil was higher in the sites under long cycles of 30 and 10 years as compared to a short cycle of 5 year. A month, after burning, there was a sharp decline in concentration

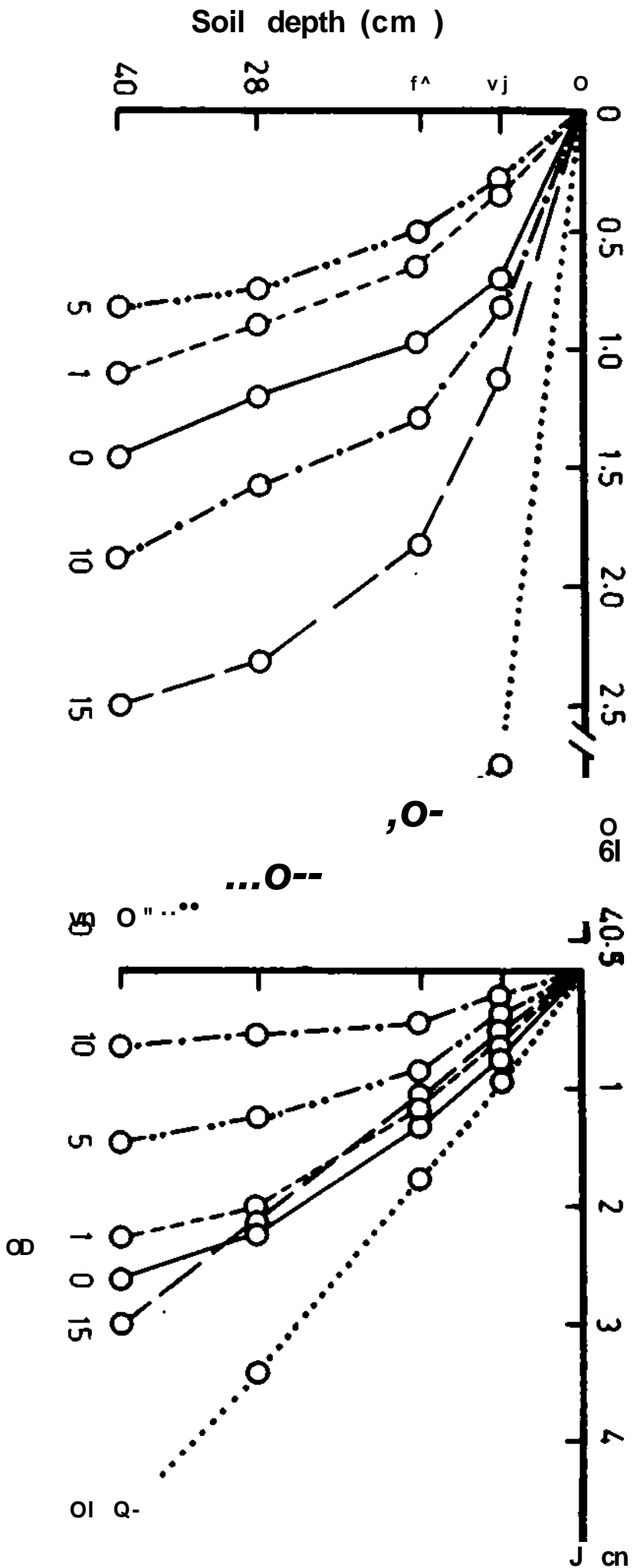
Table 4.6

Concentration of available phosphorus (mg/100 g) in the soil under forested fallows of various ages.

Depth of soil ( cm)	Age of the fallow (year)					
	0	1	5	10	15	50
0-7	0.68	0.35	0.28	0.78	1.08	10.70
7-14	0.25	0.25	0.19	0.45	0.65	7.50
14-28	0.13	0.12	0.11	0.14	0.25	4.70
28-40	0.11	0.10	0.05	0.14	0.15	3.60

Fig. 4.5. Changes in cumulative quantity of available phosphorus (A) and potassium (B) within a soil column of 40 cm depth under fallows of various ages.

O———O , 0 year; O———O , •  
 1 year; O—•—Q 5 year; O———O , 10 year;  
 O———O » <sup>15</sup> year; Q.....Q, 50 year.



of all cations in the top soil layer in all the three sites. This decline persisted upto a period of three months for calcium and magnesium but continued upto 12 months in the case of potassium. After a year of cropping, all the three jhum sites showed a slight improvement in cations compared to the level before the burn. Cationic concentration at lower depths (7-40 cm) was not significantly affected during the 1 year period (Fig. 4.4, 4.5, 4.9).

The total amount of various cations to a depth of 40 cm increased markedly after the burn and then declined during subsequent months. This pattern was more pronounced under 30 and 10 year jhum cycles whereas the level of cations and their fluctuations were less pronounced under a 5 year cycle. At the end of the 12-month period the level of the cations remained more or less at the same level as that before the burn. It is also interesting to note that while calcium and potassium level in the soil profile were very close to one another after the burn in a 30 year jhum cycle, the level of potassium was markedly higher than that of calcium after the burn in a 10 year jhum cycle (Fig. 4.6, 4.7, 4.8).

In a 1 year fallow, the soil calcium and magnesium levels were fairly close or slightly higher than that in a 0 year fallow left immediately after 1 year of cropping.

**Table 4.7**  
**Changes in concentration (meq./100 gm) of potassium through the soil**  
**profile after burn and during cropping in sites under different**  
**Jhum cycles**

Sampling time (days)	Soil depth (cm)	Jhum cycle (years)											
		0-7	<sup>30</sup> <b>7-14</b>	14-28	28-40	<b>10</b>				<b>5</b>			
						<b>0-?</b>	7-14	14-28	28-40	0-7	7-14	14-28	<b>28-40</b>
-1		0.64	0.56	0.51	0.61	0.51	0.43	0.41	0.31	0.35	0.46	0.18	0.10
1		7.95	0.67	0.64	0.77	<b>8.20</b>	0.51	0.39	0.29	2.25	0.41	0.20	0.14
30		1.65	0.77	0.78	0.71	1.64	0.48	0.46	0.20	0.82	0.52	0.23	0.20
90		0.89	0.71	0.66	0.78	1.20	0.56	0.45	0.23	0.46	0.48	0.20	0.15
365		0.66	0.46	0.46	0.74	0.66	0.56	0.38	0.25	0.51	0.50	0.20	0.13

Table 4.8

Changes in available calcium (meq./100 g) of calcium through the soil profile after burn and fallow or plow sites under different fallow cycle

Fallow time (days)	Soil depth (cm)	Fallow cycle (years)											
		30				10				5			
		0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40
		3.36	2.24	1.87	1.30	2.02	1.60	0.55	0.47	1.56	0.75	0.37	9.37
		14.97	2.22	1.74	1.19	5.86	1.54	0.67	0.37	5.12	0.90	0.44	0.35
		3.74	2.27	1.84	1.24	3.49	1.74	0.74	0.40	2.87	1.15	0.48	0.42
		3.11	2.37	1.99	1.12	2.24	1.25	0.77	0.54	2.37	1.12	0.45	0.47
		3.49	2.45	1.74	1.17	2.29	1.68	0.59	0.49	2.00	0.82	0.33	0.42

Table 4.9

Changes In concentration (aeq./100 ga) of aagnesiua through, the soil profile after burn and during cropping in sites under different Jnun cycles

Saapling tiae (days)	Soil depth (en)	jama cycle (years)											
		30.				10				5			
		0-7	7-14	14-28	28-40	0^7	7^15	14-28	28-40	0-7	7-14	14-28	28-40
		2.67	1.85	b l b D	1.90	2.15	1.85	1.89	1.93	2.36	1.85	1.12	1.02
		8.22	2.00	2.13	1.89	7.40	2.01	2.05	2.05	5*55	2.01	1.23	0.90
		3.50	2.46	2.26	1.93	3.30	2.46	1.89	2.20	3.49	2.05	1.06	1.05
		3.49	1.80	2.13	1.97	1.85	1.85	1.68	2.03	3.03	2.01	0.85	0.80
		3.70	2.36	2.05	2.13	2.20	2.15	1.85	1.94	2.87	1.43	1.19	0.99

Pig. 4.6. Changes in total quantity of potassium within a soil column of 40 cm after burn and during cropping in sites under 30 (A), 10 (B) and 5 (C) year jhum cycles.

Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28; open column, 28-40 cm depth of soil.

fig 4.6

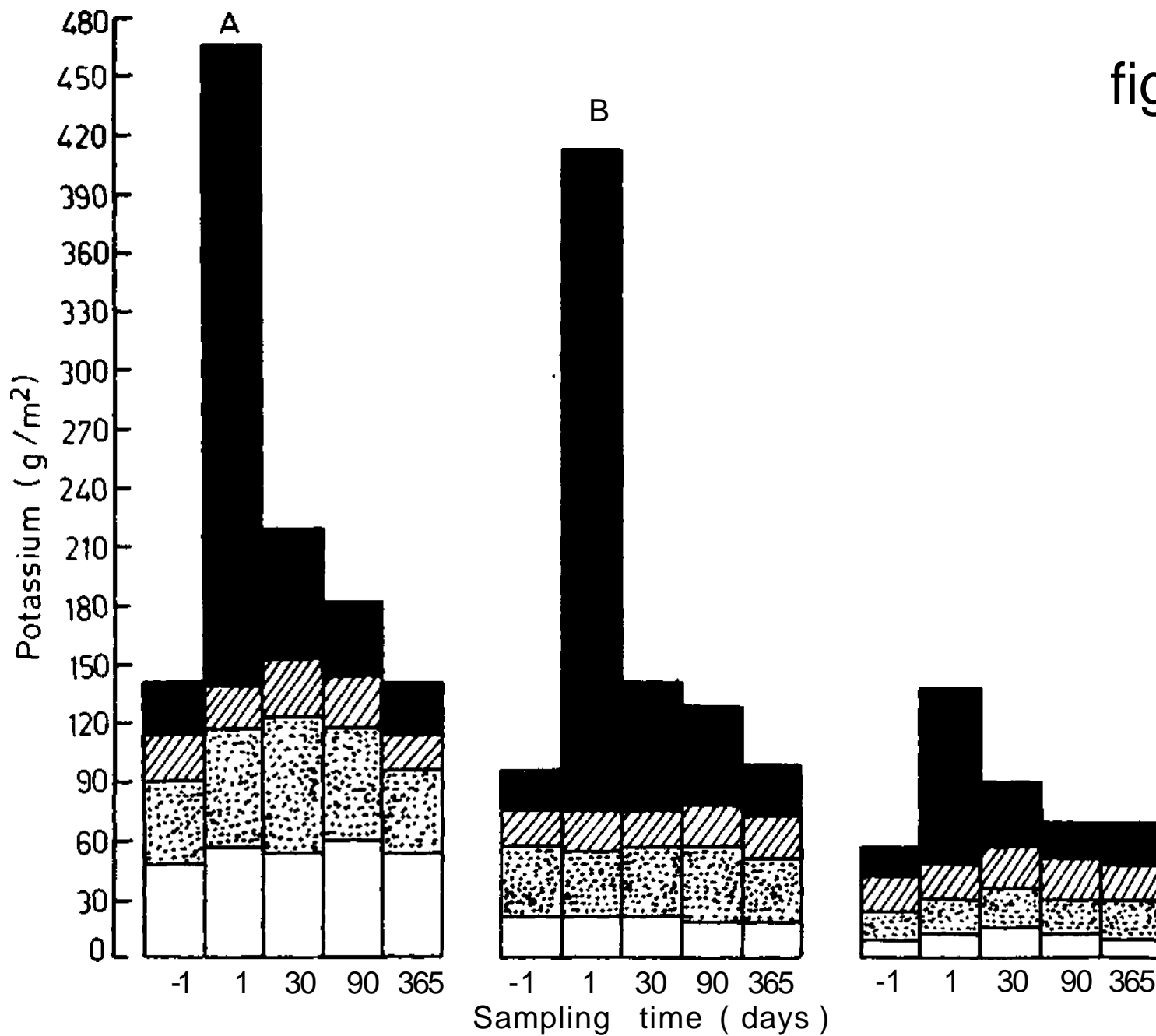


Fig. 4.7. Changes in total quantity of calcium within a soil column of 40 cm after burn and during cropping in sites under 30 (A), 10 (B) and 5 (0) year jhum cycles.

Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.

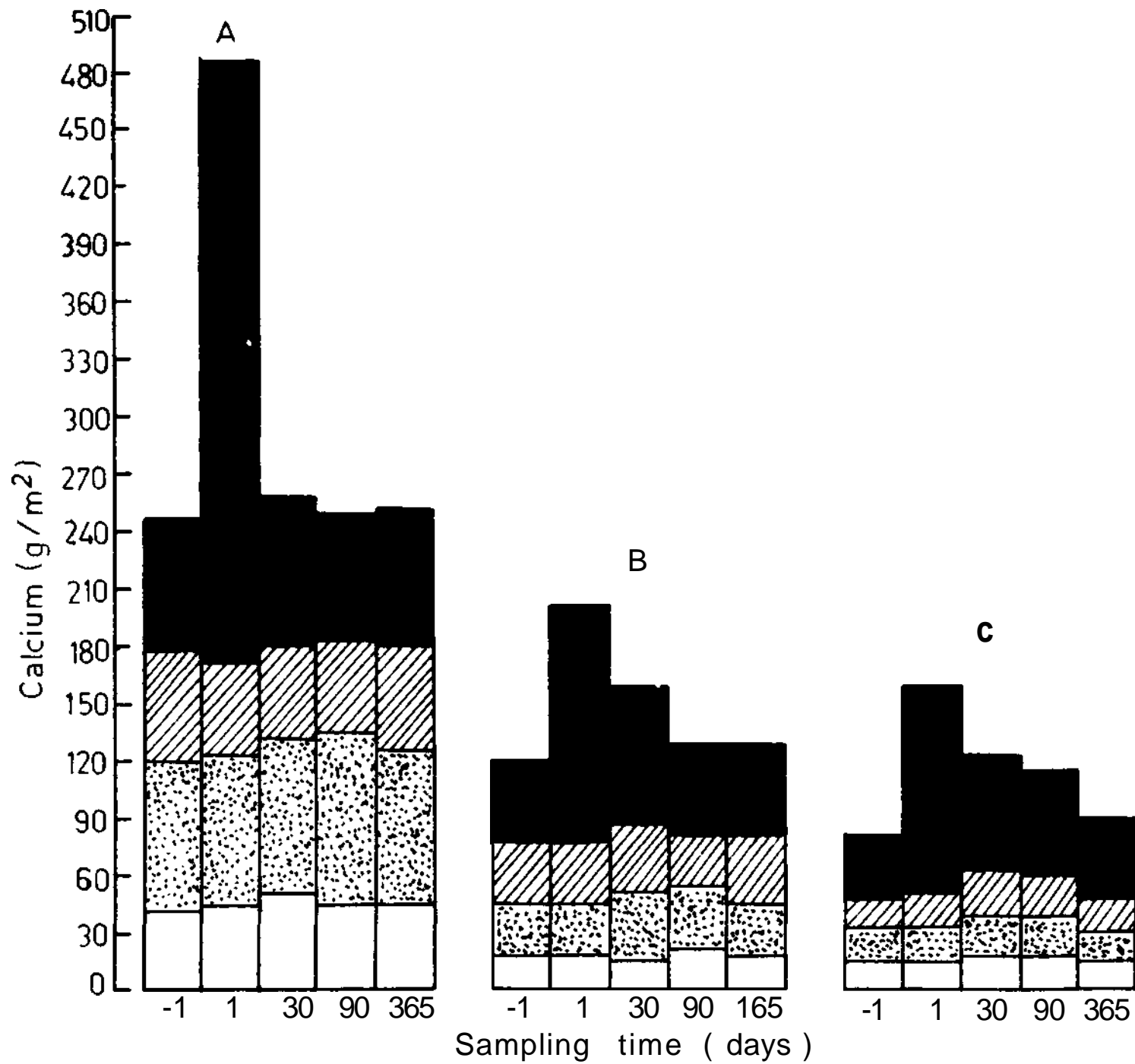
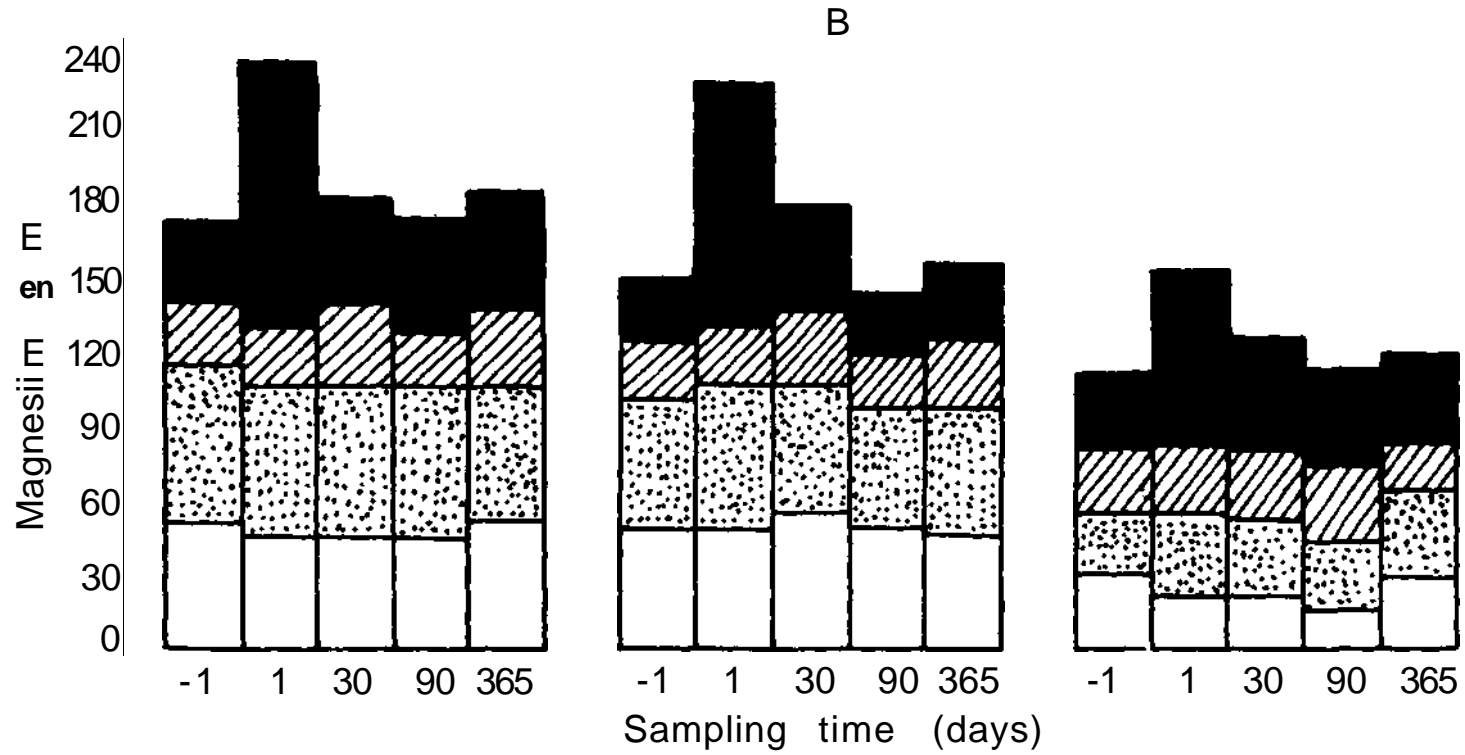


fig. u.7

Fig. 4.8. Changes in total quantity of magnesium within a soil column of 40 cm after burn and during cropping in sites under 30 (A), 10 (B) and 5 year (C) jhum cycles.

Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil\*

fig.4.8



With the age of the fallow between 5 and 15 years, the level fluctuated and even dropped significantly in some of the fallows. However, in a 50 year fallow the concentration of these two nutrients dropped markedly and was lowest at all depths. Potassium on the other hand started with a comparative high concentration in 0 and 1 year fallows, declined markedly in 5 and 10 year fallows and again recovered reaching highest concentration in a 50 year fallow (Table 440),

Cumulative amount of calcium and magnesium followed a different trend from that of potassium as noted above. • In the case of the former two, total level through the soil profile was least in a 50 year fallow and was maximum in 0 and 1 year fallows. In a 50 year fallow the depletion of these two nutrients was maximum with increase in depth of the soil. On the other hand, in a 50 year fallow potassium level was maximum and its enrichment through depth was also high. Least level of potassium in the soil was observed in a 10 year fallow (Fig. 4.5 B<sup>^</sup>C+.i).

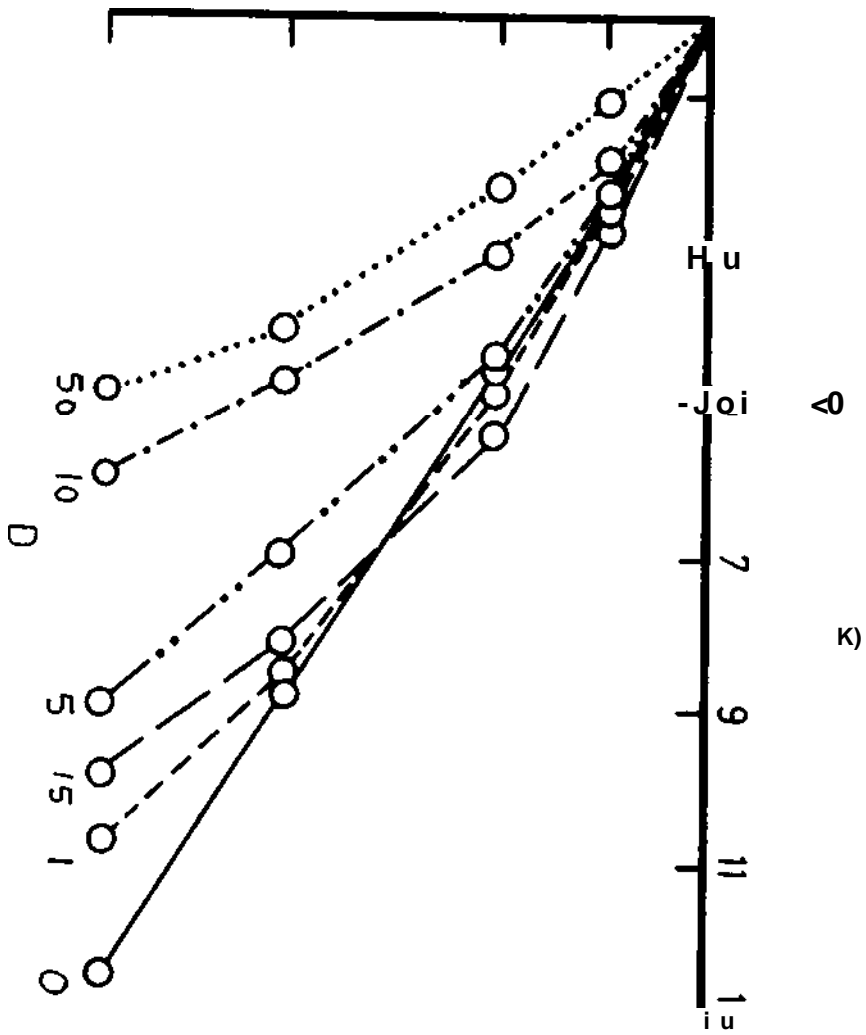
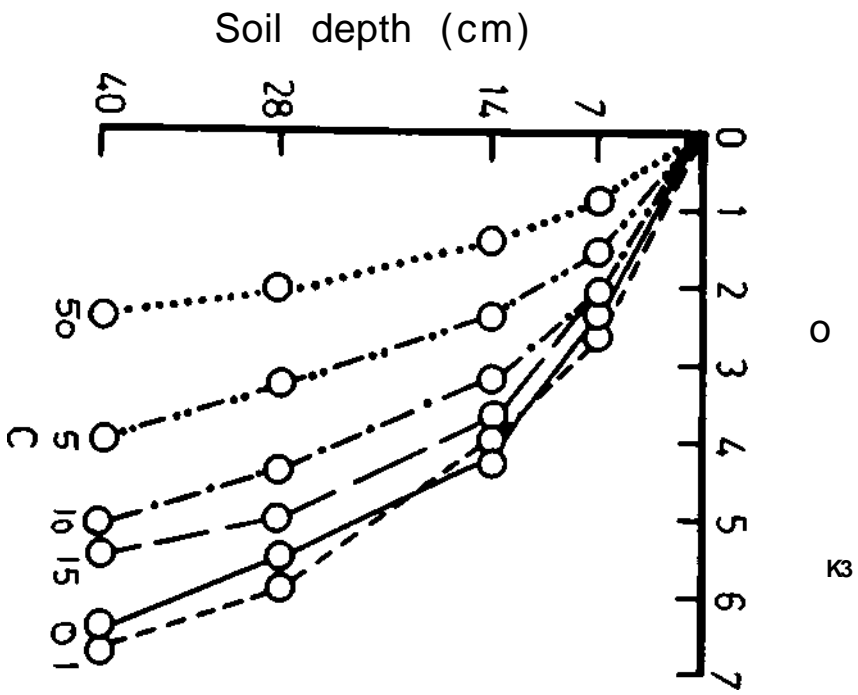
### ***m***

Under all the three jhum cycles, pronounced increase in pH of surface soil only (0-7 cm) was recorded immediately after burning, followed by a sharp decline in subsequent



Fig. 4.9. Changes in cumulative quantity of calcium (A) and magnesium (B) within a soil column of 40 cm under fallows of various ages\*

Q \_\_\_\_\_ O\* 18 year, O ..... O 50 y\*\*\*r\*  
 O\_\_\_\_\_O, 0 year i O\_0t 1 year |



months reaching more or less the original value after 1 year of cropping which was in the range of 5.90 to 6.64, pH did not fluctuate significantly at lower depths (7-40 cm) during the year (Table 4.11).

In the jhum fallows of 0-15 years, pH declined with increase in soil depth but in a 50 year fallow, pH remained steady with increase in depth. pH of the soil was always acidic ranging between 5.20 and 6.50 (Table 4.11).

#### DISCUSSION

A number of changes occur in the physio-chemical characteristics of the soil subsequent to slash and burn. Slashing the vegetational cover brings about a number of micro-environmental changes in the site due to increased insolation and subsequent changes in soil moisture and atmospheric humidity in the site. The atmospheric and surface soil temperature conditions are also altered significantly due to clear cutting of the forest. These changes along with other changes in soil chemistry get accentuated after a low or high intensity burn before cultivation of the site.

The significant reduction in soil carbon content immediately after fire under a 30 or 10 year jhum cycle

**Table 4.11**

**Gkanges in pH tkrougk tke soil prefile after bura aad during  
ersppiag in sites under different jkum cycles.**

San tine (days)	fling dep (en)	Jkan eyele (years)											
		tk	50	Ssll		10				5			
		CT	7-14	14-26	28-40	CT	7-14	14-28	28-46	2P?	7-14	14-28	jti-46
		6.6	6.3	6.0	5.6	5.9	5.6	5.4	5.1	6.0	5.6	5.4	5*3
		8.7	6.4	5.9	5.6	9.0	5.7	5.6	5.2	7.5	5.6	5.4	5.2
		7.2	6.4	5.9	5.5	7.5	6.0	5.7	5.2	6.3	5.7	5.4	5.2
		6.9	6.5	o, y	5.5	6.6	o» y	5.7	5.3	5.7	5.5	5.5	5.3
		6.4	6.3	5.7	5.6	6.0	5.8	5.6	5.2	5.8	5.4	5.4	5*2

Table 3.14..  
 Changes in soil pH under forested fallows of various ages

Soil depth (cm)	Age of the fallow (Years)					
	0	1	5	10	15	50
0-7	6.0	6.5	6.1	5.9	6.1	5.7
7-14	5.8	6.0	5.6	5.6	5.5	5.8
14-88	5.7	5.8	5.4	5.3	5.6	5.7
28-40	5.3	5.4	5.3	5.2	5.4	5.8

could be accounted as due to a high intensity burn which is done twice for completion of this process. Under short jhum cycle of 5 year, however, since quantity of slash is much less, the burn is also of low intensity and therefore the surface soil humus remained less affected. It may be noted here that the site under longer jhum cycles start with higher carbon and high intensity fire depletes it rapidly in the top soil. At the time of cultivation loss of organic matter from the soil due to decomposition is likely to be faster due to high insolation and also due to rapid surface run-off of soil. After an initial period of depletion of organic matter during cultivation, there is a period of recovery of humus in the soil, derived from slash of the harvested crops and of the weeds. Because of higher level of organic content maintained after a year of cropping, long jhum cycle sites may be able to sustain another year of cropping. After a year of chopping there was a net loss of carbon compared to that before the burn, an observation also made by other workers (Joachim & Kandiah, 1948; Nye & Greenland, 1964; Zinke et al, 1978; Jha et al, 1979), Juo & Lai (1977) showed that under shifting agriculture in West Nigeria, due to fast rate of decomposition of organic matter under continuous cropping, 16 m tons/ha/year of dry

plant material is required to maintain soil organic matter in the surface soil at a level comparable to soil under secondary forest. The depletion of organic matter depends upon the intensity of cropping, type of fallow vegetation and the ratio of cropping to fallow period. With optimum cropping and fallow period, the humus in the soil could be maintained at a relatively high level even after many years of shifting cultivation (Caulter, 1960; Reed, 1951; Birch & Friend, 1956).

Accumulation of organic matter and nutrients by the native second growth vegetation is one of the important functions of the fallow period. It is the return of the organic matter to the upper soil depths which accounts for the restoration of soil fertility and the main pathway of it is the litter fall and its subsequent decomposition. The depletion of organic matter in the surface soil continued through the early successional fallows upto about 5 years. This was mainly due to low return of litter

during the initial colonization and growth of the vegetation in the fallows dominated by species like Imperata cylindrica and Eupatorium odoratum and also due to faster decomposition in these open sites. This trend in reduction of soil humus upto a 5 year fallow period could be one of

the reasons against a short jhum cycle which has become so common in present times. Maximum level of soil humus is reached in a fallow 10 year old, though a slightly lower level was maintained in the soil under a 50 year fallow. Lau delo t & Meyer (1954) and Ewel (1976) have made similar observations and conclude that organic matter production in mature stand is less compared to a secondary serai forest.

Similar to the pattern of humus content in the surface soil, total soil nitrogen declined sharply after the burn under longer jhum cycles compared to a short 5 year cycle. This is partly due to low nitrogen build up in the fallows before the burn under the 5 year cycle and also due to low intensity burn. Under longer cycles, the build up of nitrogen was higher in the soils at the end of the fallow period and the soil experienced a high intensity burn resulting in greater loss of nitrogen through volatilization from the surface soil.

Nitrification after the burn was accelerated due to high microbial activity, due to rise in pH and temperature of the surface soil (Griffith, 1949; Moore & Jaiyebo, 1963; Ahlgren & Ahlgren, 1965). The increase in nitrification after clear cutting of forests has also been attributed by some

workers as due to the removal of chemical inhibitors (Smith et al., 1968). The intact vegetation of the ecosystem causes allelopathic inhibition of nitrifying organisms in the soil (Rice, 1974; Melillo, 1977), thus reducing the rate of nitrification. The level of  $\text{NO}_3\text{-N}$  fell rapidly because of its removal by rain and also due to absorption by fast growing weeds and crops species.

Though there was net loss of nitrogen from all the sites after a year of cropping compared to that before burn, longer jhum cycle sites had higher nitrogen status compared to site under a 5 year cycle and therefore, probably sustain cropping for a longer duration. It may be noted that according to Nye and Greenland (1960) response of nitrogen fertilizer are small where fallows are long (10 year or more) but in land more intensively cultivated with short fallows, the responses become larger: •

The decline in nitrogen level upto 5 year during revegetation of the fallow could be partly due to low litter production and also due to rapid utilization of nitrogen by the fast growing plant cover. As for carbon, nitrogen level in the soil also reached its peak in a 10 year old fallow. The comparatively low level of both carbon and nitrogen

attained in a 15 year fallow compared to a 10 year *one* could be explained as due to accidental spread of ground fire from slash and burn in adjoining areas\*

Humus level in the soil in general remained low due to its faster rate of mineralization. Only a fraction of the organic matter gets incorporated into the soil (Jenny & Ray Chaufthuri, 1960; Nye & Greenland, 1960) and this accounts for the low G/N ratio during all phases of jhum cycle.

The increase in available phosphorus after fire was slight under jhum cycle. The rapid build up of available phosphorus level a month after the burn could be due to :

(i) release from the ash after the rainfall occurs (ii) increase in the soil pH and the consequent increase in microbial activity (Ahlgren & Ahlgren, 1965) which may result in rapid mineralization of the residual humus. This build up of available phosphorus was maximum under longer jhum cycle and minimum under the short 5 year cycle which may be related to the amount of slash, intensity of burn and the consequent lower pH level and the generally low humus content. The sharp decline in available phosphorus 3 months after the burn may be due to rapid absorption of this element by crops and weeds, and also due to removal by run-off at a rapid rate when the

plant cover is still developing. After a year of cropping, the available phosphorus level was more or, sometimes even slightly higher than that before the burn (Nye & Greenland, 1960; Zinke et al, 1978).

During early phases of development of vegetation upto a 5 year fallow, there is a gradual depletion in available phosphorus throughout the profile reaching a minimum under a 5 year second-growth fallow. This is followed by a rapid build up through 10, 15 and 50 year fallows, .The accumulation of phosphorus particularly in the surface **layers** of older forests may be due to transfer of phosphorus from the deeper layers, &f. the-"soil to thf'upp^ter stratum through litter fall (**Bye** & Bertheux, 1957;" Russel, 1968).

There~are four sources of basic cations in the upper layer of the soil : that from weathering of parent material, decay of soil humus, decay of surface organic matter and the ash from burning the slash. The importance of fire in slash and burn agriculture is seen from the fact that there is a quick release of cations after the burn on the surface layer of the soil (Nye & Greenland, 1960; Zinke et al, 1978) with a high level being maintained even in a fallow that is a year old, after cropping, as seen from the

present results. The greater quantity of cations released after the burn under longer 3hum cycle is understandable due to the larger quantities of slash that was burnt compared to that under a 5 year cycle. The amount of calcium and potassium released under a 30 year 3hum cycle was fairly high due to high accumulation of these nutrients in the dicot trees and bamboo (Dendrocalamus hamiltonii). It may be worth noting there that Dendrocalamus hamiltonii is a heavy accumulator of potassium. This species being the predominant component in a 10 year fallow, the level of potassium is much higher compared to other cations after the burn of the site under a 10 year cycle. It is interesting to note that the level of potassium in the soil of a 10 year fallow is significantly low which is due to heavy accumulation of this nutrient in the living biomass of Dendrocalamus hamiltonii. thus depleting the level in the soil. Potassium levels in the soil and that in the living biomass are thus inversely related in a ten year fallow. Thus the quantity and quality of slash determine the quantity and proportion of the various cations released after the burn.

Increase in cationic content at all the three sites was for a brief period after the burn and the abrupt decline

in level  $baao_A$  due to heavy losses of ash due to blow-off by strong wind prevalent during the dry months of March - April and the subsequent decline due to surface run-off and percolation losses. The level of cations in the soil after a year of cropping, under a 30 year *jhun* cycle, was much higher than the level at any time under 5 year cycle and therefore a second year of cropping is sustainable under a longer *jhun* cycle as also reported by Nye & Greenland (1960).

The exchangeable cations are depleted from the top column of the soil as the forest fallow develops due to the rapid absorption by the developing vegetation and also due to erosion and percolation losses. Potassium accumulation by *Dendrocalamus hamiltonii* in a 10 year fallow is an example of rapid transfer of this nutrient from the soil pool to the living biomass compartment as discussed earlier. .-\_\_\_\_\_?

Valentine (1976) working with the changes in soil chemical characteristics after clear falling and burning of forest in &gt;uth-Utestern Australia also reported that the level of exchangeable potassium, calcium and magnesium declined rapidly in the first 7 years after the regeneration burn; which may be due to transfer from the soil pool to the living biomass. As the age of the *jhun* fallow increased, beyond

10 years, soil cationic level and particularly that of potassium increased due to faster return of nutrients into the soil through litter fall from a mature stand of vegetation containing species like Dendrocalamus hamiltonii.

An old forest stand like a 50 year fallow discussed here, showed low level of calcium and magnesium in soil and rapid depletion of both with depth which is in contrast to the pattern observed for potassium which maintained very high levels. Thus the recharge of calcium and magnesium in the soil pool seems to be much more fire dependent whereas potassium release due to litter fall recharges the soil pool resulting in a very high level in a 50 year old fallow. It may be noted here that Dendrocalamus hamiltonii which is a dominant feature in the vegetation only upto about 20 years of regrowth of the forest accumulates potassium in the biomass upto this stage and discharges it into the soil pool when this species dies out and is replaced by dicot trees during the course of succession. Zinke, *et al* (1978) in the 'Lua' forest fallow system concludes that the sum of basic cations is highest at the beginning of the cycle at the time of slash and burn, with a gradual discharge of soil calcium and magnesium as the forest fallow regrows in contrast with potasslim which had a high level in the soil

# no

under an old forest, an observation similar to the present  
» \*  
one.

Short jhum cycle, as is seen from the present study results in very low fertility levels in the soil. Apart from this, the low yield of crops under short cycle may also be due to poor physical conditions of the soil and weed problem. A 5 year old fallow is characterised by dominance of weeds like Imperata cylindrica and Eupatorium odoratum (Eamakrishnan et al, 1980). Poor build up of soil fertility under 5 year jhum cycle is understandable because, as discussed earlier, during early stages of regrowth recovery is not possible due to short fallow period and depleting of already low level of fertility by the fast developing vegetation. Recovery of soil fertility is observable only in fallows of 10 years or older.

Crop yield after one year of cultivation declines rapidly under shifting agriculture. Apart from other considerations discussed above, the rapid decline in crop productivity in subsequent years may also be attributed as due to destruction of mycorrhiza and subsequent changes in recycling of minerals (lent & Stark, 1968). The studies done in this laboratory also support this conclusion. The destruction of

# HI

mycorrhiza population in the soil may get accentuated under very short jhum cycles.

## SUMMARY

The present study deals with fertility changes during shifting cultivation (locally called 'jhum<sup>1</sup>') and the subsequent recovery of fertility as a forested fallow developed. A comparison has been made between three jhum cycles of 30, 10 and 5 years. Depletion in soil carbon continued throughout the cropping period and extended upto a 5 year fallow. This could be one of the reasons against a short jhum cycle alongwith a similar pattern in depletion of nitrogen. Available phosphorus build up in the fallows also started only beyond a 5 year fallow period with rapid increase in 10, 15 and 50 year fallows. Cationic concentration in the soil also rapidly declined in the early phases of regrowth of vegetation. This decline was most pronounced for potassium due to the fact that Dendrocalamus hamiltonii is a heavy accumulator of this nutrient. Since this bamboo species dominates the fallow upto about 20 years, potassium build up in the soil was observable only at this stage. It is suggested that this species plays an important role in conservation of this nutrient. In a 50 year fallow, low

levels of calcium and magnesium were maintained with rapid depletion of both with depth which is in contrast to that of potassium and phosphorus. *U* In general, short jBurn cycles permit only low levels of soil fertility with very poor recovery during the fallow period. *'pas^ijgr££XQ&Ki5WS~-&£~~~* th^3"e~~reTStr3rt^ are dis-cus-sed.

CHAPTER 5

RUN-OFF AND INFILTRATION LOSSES  
RELATED TO SHIFTING AGRICULTURE  
(JHUM) IN NORTH-EASTERN INDIA.



# U3

## RUN-OFF AND INFILTRATION LOSSES BELATED TO SHIFTING AGRICULTURE (JHUM) IN NORTH-EASTERN INDIA

### INTRODUCTION

Shifting cultivation which is the predominant form of agriculture in north-eastern hill areas of India is locally called 'Jhum'<sup>1</sup> and involves the cutting of the forest, burning the dried biomass, mixed cropping for a period of 1 or sometimes 2 years and then reverting the land to its natural vegetation so as to allow restoration of soil fertility. The jhum cycle has become very short (4-5 years) in the recent past, from more desirable 20-30 years period for the cycle. Longer cycles not only permit maintenance of a high level of soil fertility (Ramakrishnan & Toky, unpublished) but also favour regeneration of a good forest cover (Ramakrishnan et al, 1980).

The present study on Jhum cultivation was done at Burnihat which is located in the Khasi hills of Meghalaya at 26.0 N & 91.5<sup>E</sup>. Here this practice is done by one of the tribes of Meghalaya namely-the 'Garos'. The climate at Burnihat is hot and humid with an average rainfall of 220 cm but during the study period in 1978 the rainfall was only 142 cm. Climate could be divided into three

distinct seasons. The dry and windy summer extends from mid-February to April with average maximum temperature of 33°C and minimum temperature of 9°C. The rainy monsoon season extends from May to October. This is a warm period with high humidity. The mild winter with an average maximum temperature of 25°C and an average minimum temperature of 5°C extends from November to mid-February. This period is practically rainless except for a few winter showers. The angle of the slope varies from 20° to 40°. The soil is of lateritic origin.

Clear cutting of forest followed by burning of the slash and cultivation on steep slopes affect the amount of water passing through the soil sub-system, dissolved substances and particulate matter lost from the soil. Losses also occur at the time of burning through volatilization (De Las Sales & Folster, 1976) and later on due to blow-off of the ash from the burnt site due to strong winds preceding the rains. Because of the virtual elimination of transpiration, increased quantities of water pass through the deforested ecosystem resulting in loss of sediment and nutrients through run-off and percolation. Moreover, the concentration of dissolved substances in

# US

water are increased due to (i) accelerated decomposition, nitrification and mineralization and (ii) absence of nutrient uptake by the vegetation (Likens et al, 1978). The present study, therefore, deals with the losses of various nutrients through wind and water after slash and burn of the forest vegetation in three sites under 30, 10 and 5 year hum cycles.

## METHODS OF STUDY

Three freshly burnt fields under 30, 10 or 5 year hum cycles were selected. While selecting the field, care was taken to ensure comparable slope conditions (32° average), exposure and soil type. Ash samples from a freshly burnt field were collected along a line transect from top, middle and bottom of the field. Fifteen such samples representing five replicates from each part of the

\*

2

hill were collected from an area of 100 cm for field estimation of ash. For chemical analysis ashing was completed in a muffle furnace at 500°C. The ash was dissolved in dilute HCl for cations and in HgSO<sub>4</sub> for phosphorus, and this was analysed for various elements.

For studies pertaining to run-off water and sedimentation, the loss from a confined area of 1x10m.

## U6

along the slope was collected in large drums of 200 l. capacity and periodically removed for analysis. Percolation studies were done using the simple lysimeter of the Russian type (Buckman & Brady, 1960). The soil was cut out vertically to expose the profile. A tunnel was excavated at a depth of 40 cm (this is the depth to which most roots penetrate) and a collector of 30x30x15 cm was placed inside the tunnel. By pressing from below, the rim of the collector was firmly inserted into the undisturbed soil above. The water percolating through the soil was tapped out into receptacles from time to time. This method was found to be satisfactory for comparative purposes.

The analyses of extracts of ash as well as water samples were done following the methods given by Allen (1974). Calcium and magnesium were analysed by<sup>tint.</sup> EDTA titration method while potassium was estimated by<sup>ine,</sup> flame emission method.  
A

NO<sub>3</sub>-N was estimated by<sub>A</sub>phenol-disulphonic acid method, PO<sub>4</sub>-P and total phosphorus were estimated by<sup>A</sup>molybdenum blue method, both colorimetrically.

### RESULTS

Production of ashes

Ash production after the burn<sup>iV^A^A^A</sup> was maximum in the

## H7

field under a 30 year jhum cycle and minimum under a 5 year cycle. Considerable proportion of the ash that was released after the burn was lost due to strong wind prevalent in the area during March - April before the start of the monsoon. While the total amount of ash lost from a unit area was more under longer jhum cycles, the percentage of the total production that was lost from the site declined with shortening of the cycle (Table 5.1).

Calcium concentration in the ash/was markedly higher in the field under a 30 year jhum cycle but that of potassium was higher in the field under a 10 year cycle. Magnesium concentration/was not very much different under any of the three cycles. Total calcium liberated through ash was 8.2-fold under a 30 year cycle compared to a 5 year cycle where as that of magnesium was less than 2-fold. The amount of potassium liberated was maximum in the field under 10 year cycle and minimum in the field under a 5 year cycle, 30 year site being intermediate between the other two. Whilst the loss of calcium and magnesium due to ash being blown off from the field decreased with the shortening of the cycle, the loss of potassium was maximum in the field under a 10 year cycle due to higher concentration of this nutrient in the ash at this site. The phosphorus concentration

Table 5.1.

Total quantity of ash liberated after the burn and the amount blown off in agro-ecosystem under various jhum cycles.

Jhum cycle (yr)	Total ash liberated <sup>id</sup> (m ton/ha)	Total ash blown off (m ton/ha)	Ash blown off (*)
30	17.390+2.20	8.170+0.80	46.98
10	13.800+0.28	8.190+0.45	59.25
5	6.850+0.93	1.940+0.95	28.32
Mean + Standard Srror			

## U9

in ash increased with shortening of the cycle. However, the total amount of this nutrient released from ash declined under cycles. The quantity of phosphorus lost through blow-off was markedly much lower under a 5 year cycle compared to 10 or 30 year cycles (Table 5.2).

### Hydrology:

In a freshly burnt site the run-off and percolation losses are related to the length of the jhum cycle so that the water loss under a short cycle is heavier. Further, clear-cutting the fallows increased the run-off loss of water. The run-off loss of water was least in a 10 year fallow. Percolation loss of water in a 10 year fallow much less than in a freshly burnt site under 5 or 10 year jhum cycles but was approximately the same as under a 30 year cycle. While the proportion of run-off loss compared to percolation loss of water was higher in freshly burnt sites, this was narrowed down in 5 and 10 year fallows. The loss of sediment from a freshly burnt site also increased with shortening of the jhum cycle. Further, the sediment loss declined sharply with the development of a vegetational cover. Thus loss of 22-30 m.tons/ha from a freshly burnt site reduced to 0.76 m.tons/ha under a 10 year fallow [(Table 5.3)].

Table 5.2.

Total quantity of nutrients liberated through ash and the amount lost through bloun-off in agro-ecosystem under various jhum cycles.

<b>Co,</b>		<b>J2i.</b>		<b>NUtvtverti</b>		<b>Co,</b>		<b>J2i.</b>		<b>NUtvtverti</b>	
Cone, in ash (%)	Total amount released (kg/ha)	Total amount blown off (kg/ha)	Cone, in ash (%)	Total amount released (kg/ha)	Total amount blown off (kg/ha)	Cone, in ash (%)	Total amount released (kg/ha)	Total amount blown off (kg/ha)	Cone, in ash (%)	Total amount released (kg/ha)	Total amount blown off (kg/ha)
5.50	956.45	449.35	1.20	208.68	98.04	10.00	1739.00	817.00	1.80	313.02	147.06
1.40	193.20	114.66	1.10	151.80	90.09	15.00	2070.00	1228.50	1.90	262,20	155.61
1.70	116.45	32.98	1.66	113.71	32.20	10.00	685.00	194.00	2.20	150.70	42.68

Table 5.3.  
Loss of water in agro-eGO system under various jhum cycles  
and the forested fallows.

Site	Run-off water (cm)	Percolated water (cm)	Sediment (m tons/h)
Agro-ecosystem under 5 year Jhum cycle	36.64	22.92	30.050
Agro-ecosystem under 10 year jhum cycle	33.94	18.98	23.080
Agro-ecosystem under 30 year jhum cycle	29.37	14.35	22.500
5 year fallow	26.90	21.30	1.130
10 year fallow	18.50	14.20	0.760

Total rainfall during the monsoon 142.08 cm

The pattern of run-off and percolation losses of water from freshly burnt sites as given in Fig. 5.1 shows that the losses are heavy in the month of May and increased markedly during June-July and declined in subsequent months.

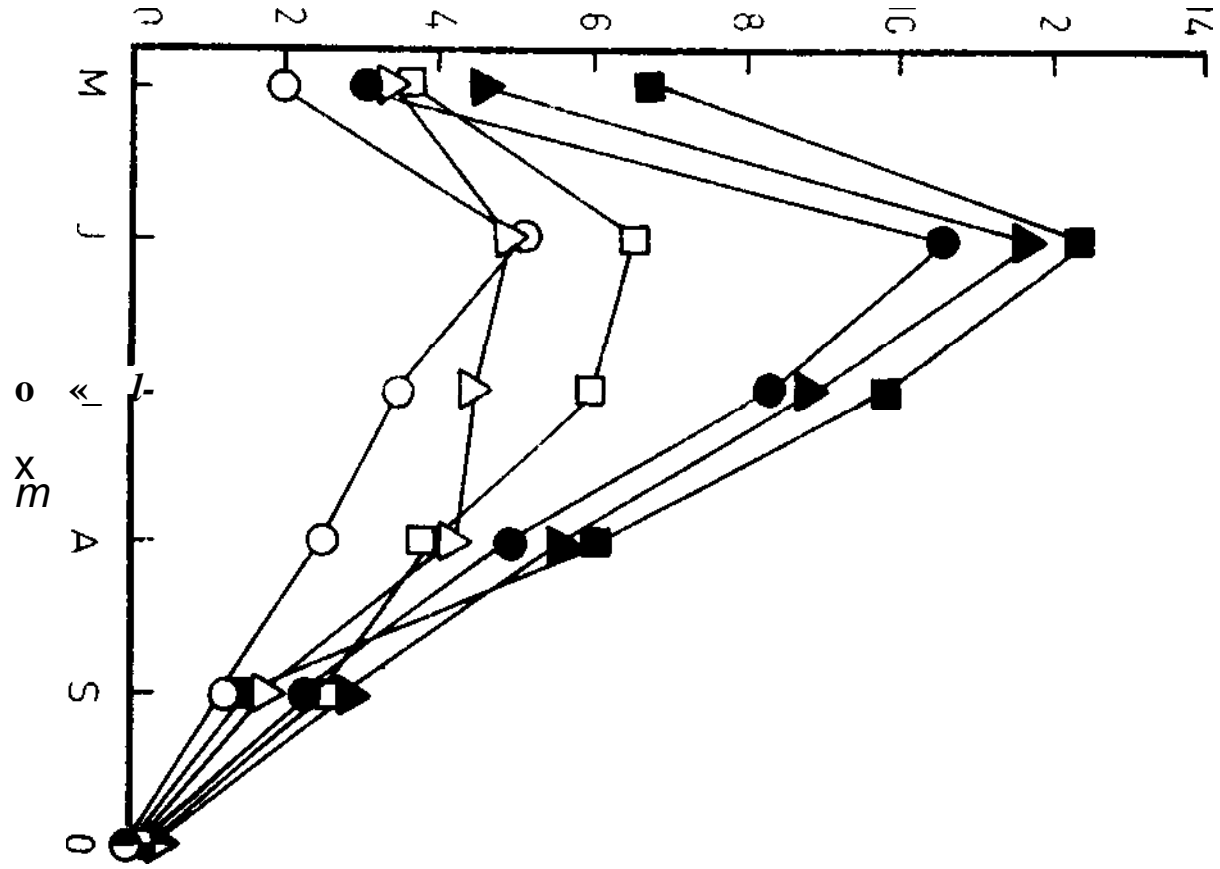
WntiHftn-t: InflHflfl through run-off in the afro-eonsystem :

During the month of May immediately after the burn, the concentration of the cations in run-off water was considerably higher in all the three fields but the concentration dropped markedly during the subsequent two months and thereafter the concentration remained at a more or less steady low level. The cation concentration in the run-off water under a 5 year jhum cycle was much lower than that under a 30 year Jhum cycle during the first one or two months only after the start of the monsoon. At this time, the concentration of cations in the site under a 10 year cycle was intermediate between the other two (Fig. 5.2).

Maximum quantity of cation losses from freshly burnt sites occurred during the early part of the monsoon between May-July, this percentage of the total loss per year working out to : calcium, 87-91%; potassium, 91-96% and magnesium, 79-92%. In the subsequent months of the monsoon, the total losses were extremely low. As noted earlier, more pronounced

Fig. 5.1. Pattern of loss of water through run-off (# , 30 year; A , 10 year; • , 5 year jhum cycles) and percolation ( O , 30 year; A , 10 year; O , 5 year jhum cycles) during the monsoon at the time of cropping after the burn in sites under three types of jhum cycles.

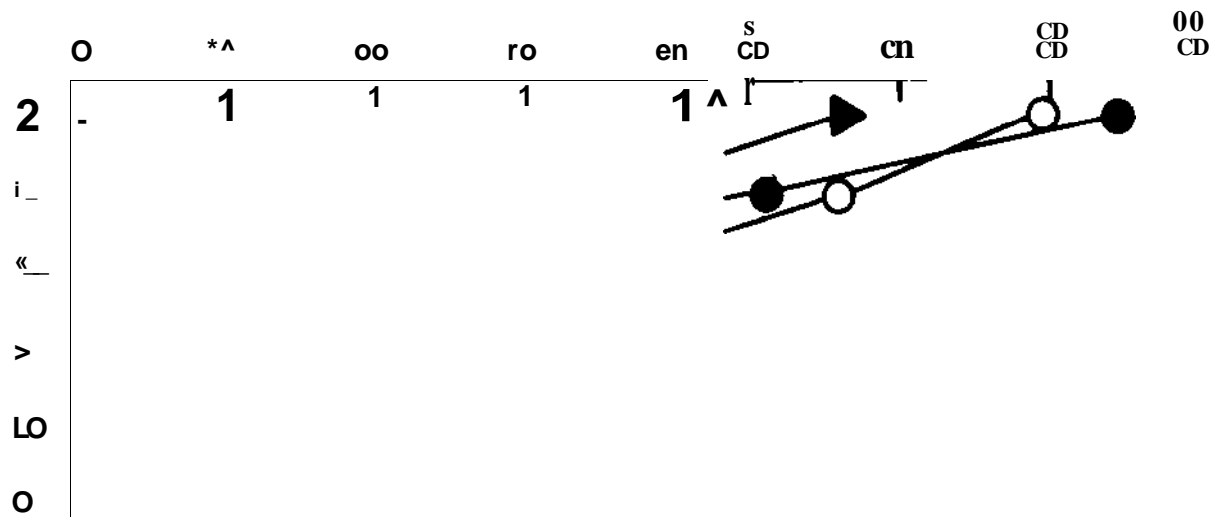
Run-off and percolated water (cm)



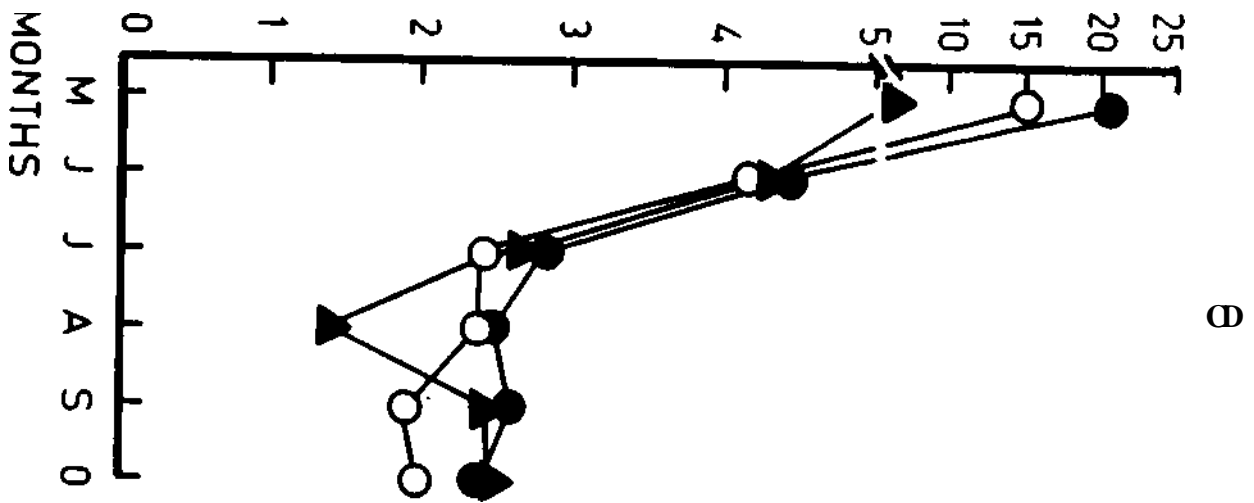
V<sup>1</sup>

Fig. 5.2. Changes in concentration of potassium (A), calcium (B) and magnesium (c) in run-off water during the monsoon at the time of cropping after the burn in sites under 30 ( • ), 10 ( O ) and 5 ( A ) year jhum cycles.

K concentration (mg/l)



Ca concentration (mg/l)



Mg concentration (mg/l)

en CD

differences between the three jhum cycles were observable only during the early part of the monsoon; during this period potassium losses were heavier under a 10 year cycle, magnesium losses were heavier under a 5 year cycle and calcium losses were high under 30 and 10 year cycles (Fig. 5.3). The total *losses during the monsoon period* were markedly higher for magnesium under\* a 5 year cycle and for potassium under a 10 year cycle; calcium losses were more or less the same for 30 and 10 year cycles and slightly lower for the 5 year cycle (Table 5.4).

Concentration of  $\text{NO}_3\text{-N}$  in run-off water in the beginning of the monsoon in the month of May was high. Only in this month was there marked difference between the three jhum cycles, with much lower concentration under a 5 year cycle compared to the other two. The concentration dropped sharply during the subsequent two months and was steady at a low level during August to October (Fig.5.4A).

Total loss of  $\text{IO}_3\text{-N}$  peaked during July and dropped sharply on either side. The amount of this nutrient lost was markedly low under a 30 year jhum cycle compared to the other two and this was pronounced only in the month of <sup>M</sup>ay (Fig. 5.4B). Total losses through run-off water during the monsoon period increased markedly with shortening

Fig. 5.3. Monthly loss of potassium (A), calcium (B) and magnesium (c) in run-off water during the monsoon at the time of cropping after the burn in sites under 30 ( • ), 10 ( O ) and ( A ) year jhum cycles.

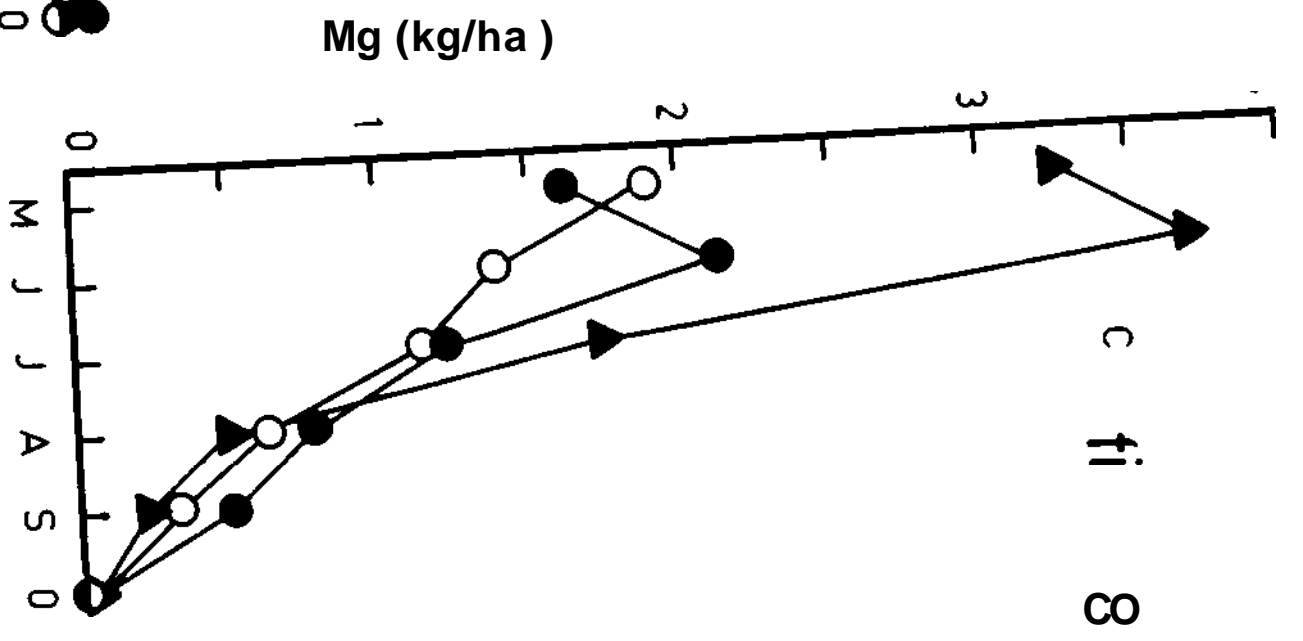
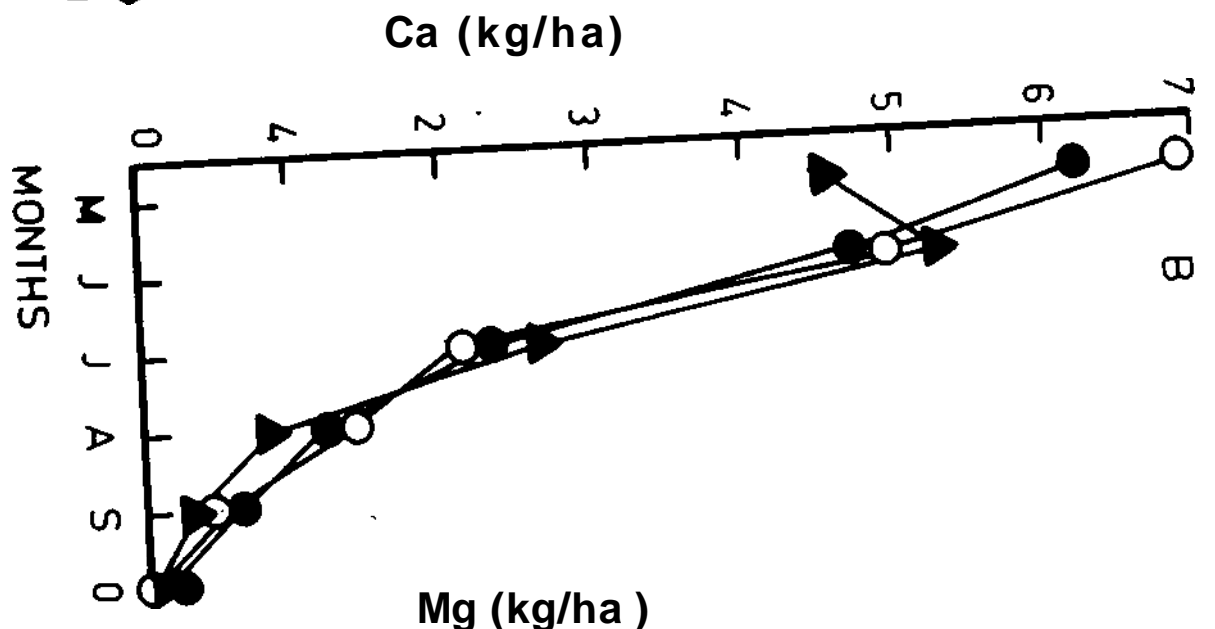
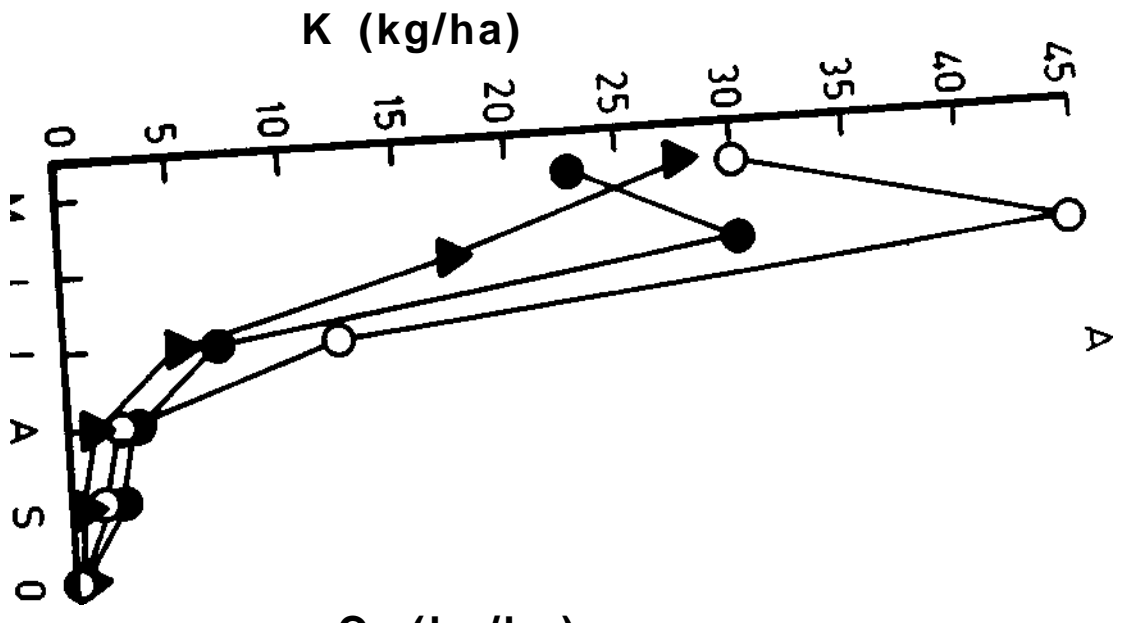
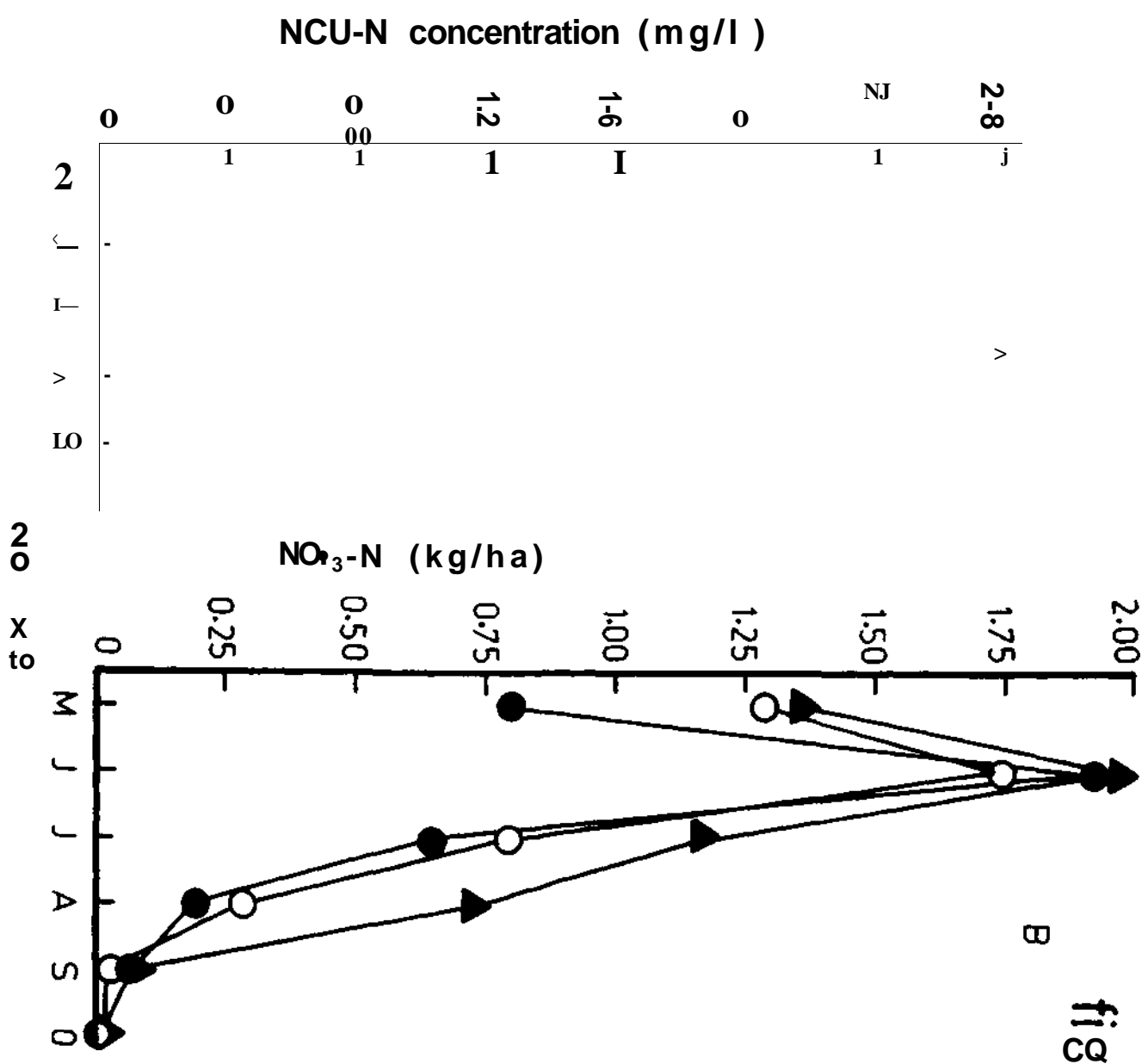


Table 5.4.  
Total loss of nutrients (kg/ha/yr) in run-off water in  
agro-ecosystem under various jhum cycles.

Element (kg/ha/yr)	Jhum cycle (yr)	Jhum cycle (yr)		
		30	10	5
Ca <sup>++</sup>	J	15.088	15.908	13.760
Mg <sup>++</sup>	i	6.323	5.427	9.475
K <sup>+</sup>	i	64.660	91.156	51.025
NO <sub>3</sub> -N	1	3.663	4.152	5.296
PO <sub>4</sub> -P	1	1.146	1.300	0.858

Fig. 5.4 A & I . Changes in concentration (A) and monthly loss (B) of  $\text{NO}_3\text{-N}$  in run-off water during the monsoon at the time of cropping after the burn in sites under 30 ( • ), 10 ( O ) and 5 ( A ) year jhum cycles.

fig



of the jhum cycle (Table 5.4).

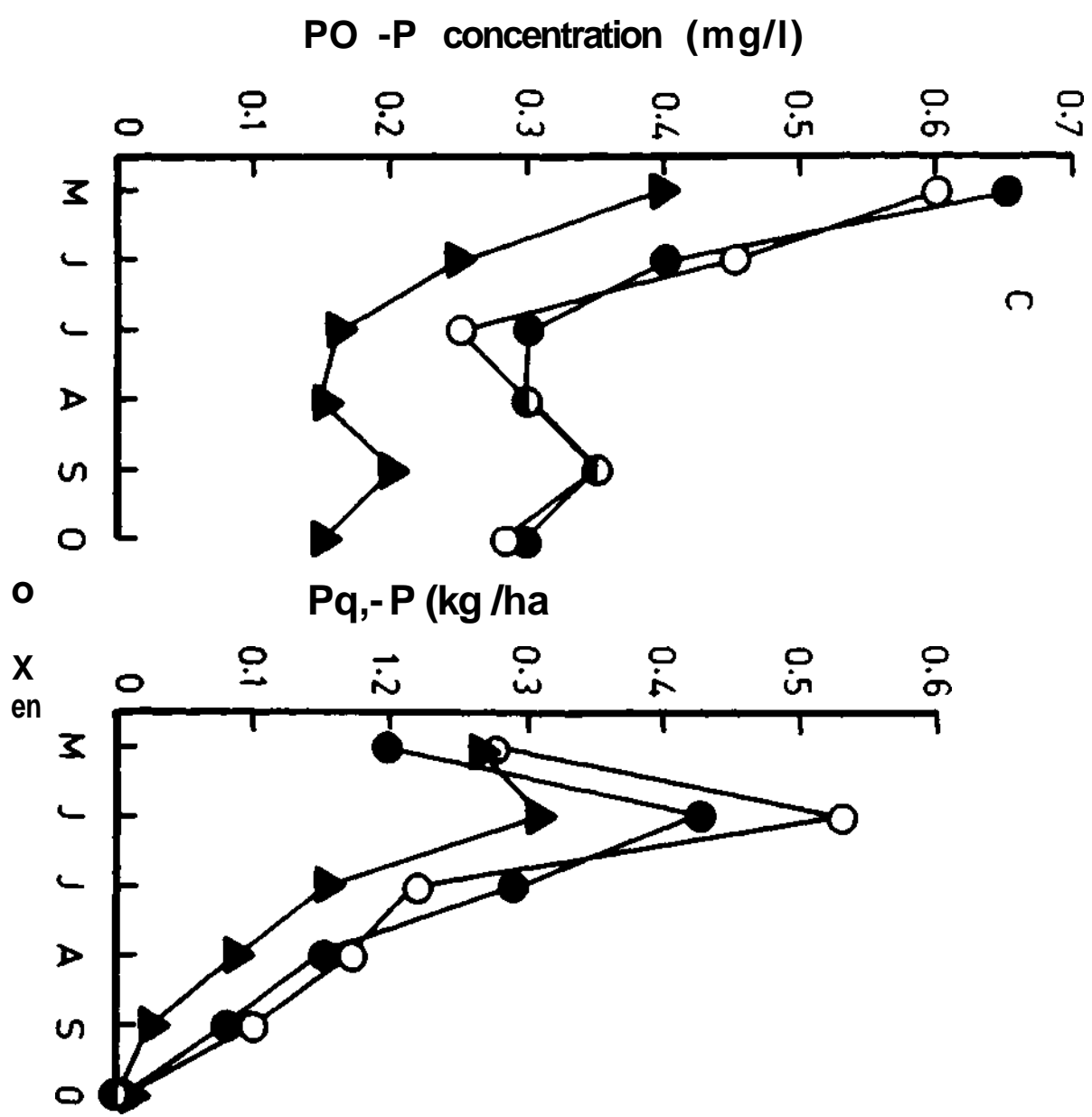
Concentration of  $\text{PO}_4\text{-P}$  in the run-off water was high in May but during June-July it dropped markedly and remained at more or less the same level during the rest of the monsoon period. During the entire period, the concentration was lower for a 5 year jhum cycle compared to the longer cycles (Fig. 5.4G).

Maximum monthly loss of  $\text{PO}_4\text{-P}$  occurred in the month of June and was markedly lower in the early and later parts of the season. The amount lost was higher in the case of 5 and 10 year cycles in the month of May but in the subsequent months 5 year cycle gave lower values compared to 10 and 30 year cycle sites (Fig. 5.4D). The total amount of  $\text{PO}_4\text{-P}$  lost during the entire monsoon was maximum under a 10 year cycle and minimum in the field under a 5 year cycle (Table 5.4).

Nutrient loss through leaching in the agro-ecosystem :

The concentration of cations in percolated water showed great monthly fluctuations in sites under 30 and 10 year cycles compared to that under a 5 year cycle. Under 30 and 10 year cycles two peaks were discernible for concentration, one in June and another in September. In general, the concentration of all the cations was maximum

Fig. 5.4 C & D . Changes in concentration ( C ) and monthly loss (J) ) of PO.-P in run-off water during the monsoon at time of cropping after the burn in sites under 30 ( # ), 10 ( O ) and 5 ( 4 ) year jhum cycles.



under a 30 year cycle and minimum under a 5 year cycle. Potassium concentration in percolated water was higher compared to calcium and magnesium (Fig. 5.5).

Total losses of all cations showed a definite pattern in that, in general, the losses were heavy during June-July. In preceding or subsequent months a sharp decline in losses was observed (Fig. 5.6). While the total loss of calcium and magnesium was not very different in sites under the three jhum cycles, the loss of potassium was *very* heavy under a 10 year cycle (Table 5.5).

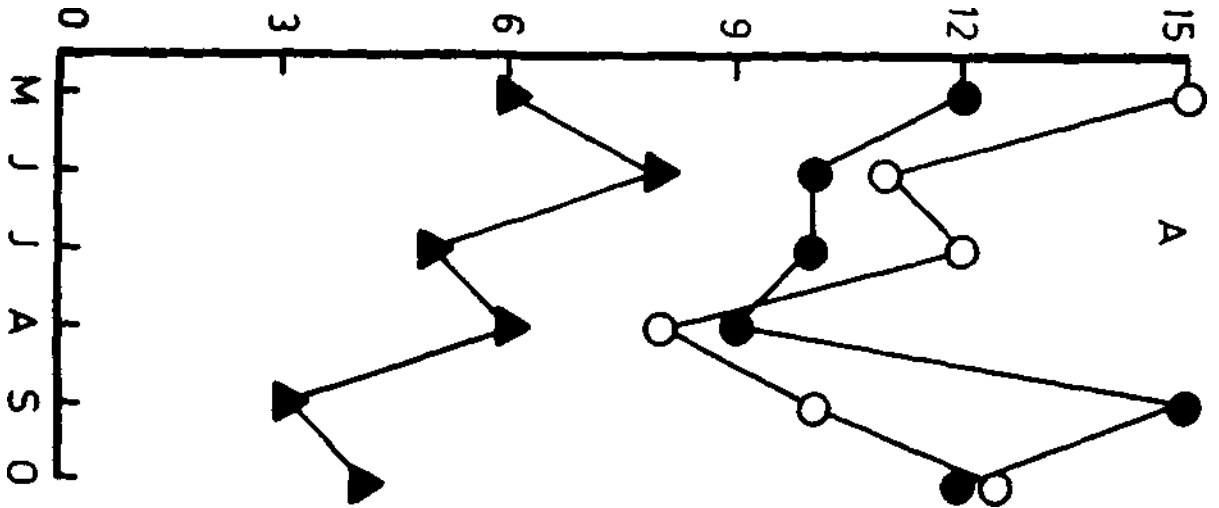
Concentration of  $\text{NO}_3\text{-N}$  in percolated water was very high in the month of May in all the three sites but declined sharply in June and July and remained more or less steady at a low level in subsequent months. Sites with longer jhum cycle showed a higher concentration of this nutrient and this difference was maximum in the month of May (Fig. 5.7A).

Leaching losses of  $\text{NO}_3\text{-N}$  was high in May but declined sharply in subsequent months (Fig. 5.7B). The total loss during the entire monsoon period was maximum under a 10 year cycle followed by 5 and 30 year cycles (Table 5.5).

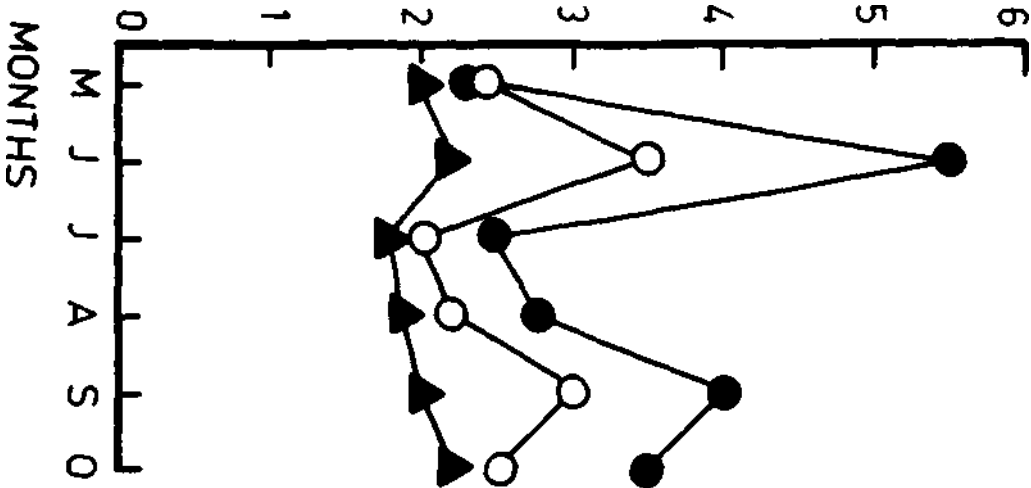
Concentration of  $\text{PO}_4\text{-P}$  in infiltrated water was generally higher during May-August dropping sharply in subsequent months

Fig. 5.5. Changes in concentration of potassium (A), calcium (B) and magnesium (C) in percolated water during the monsoon at the time of cropping after the burn in sites under 30 ( • ), 10 ( O ) and 5(A) year jhum cycles.

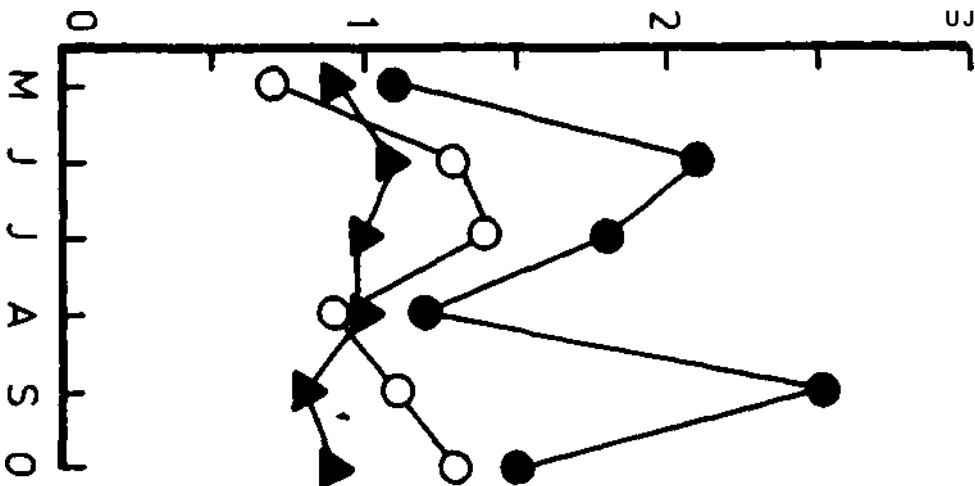
K concentration (mg/l)



Ca concentration (mg/l)



Mg concentration (mg/l)

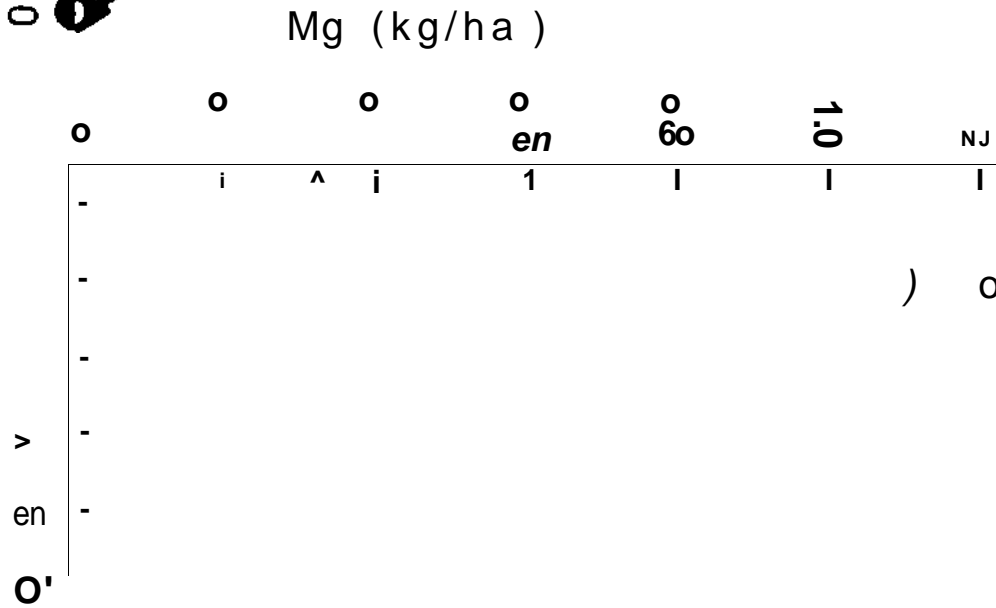
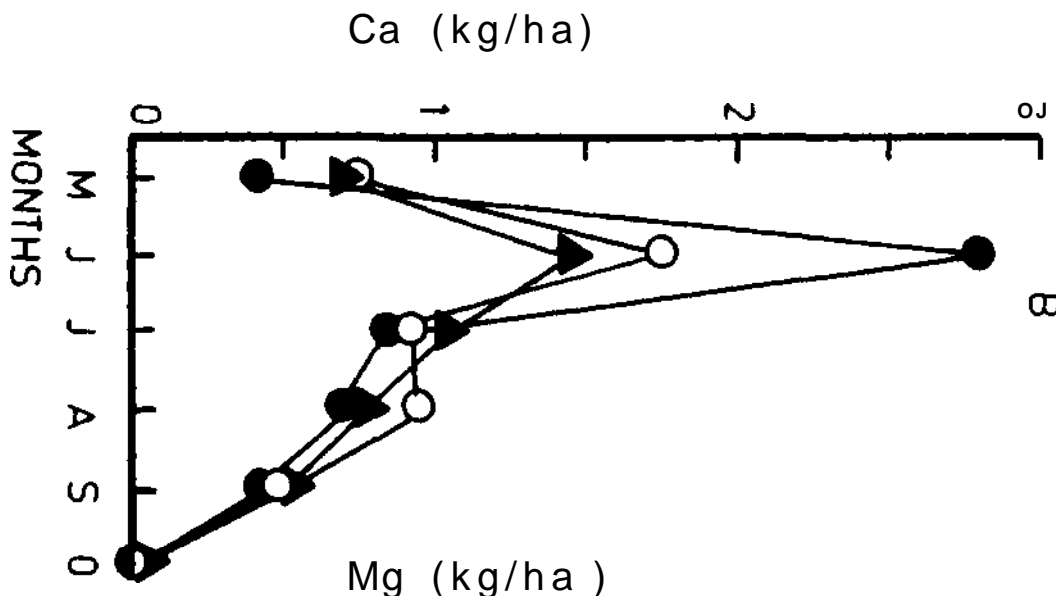
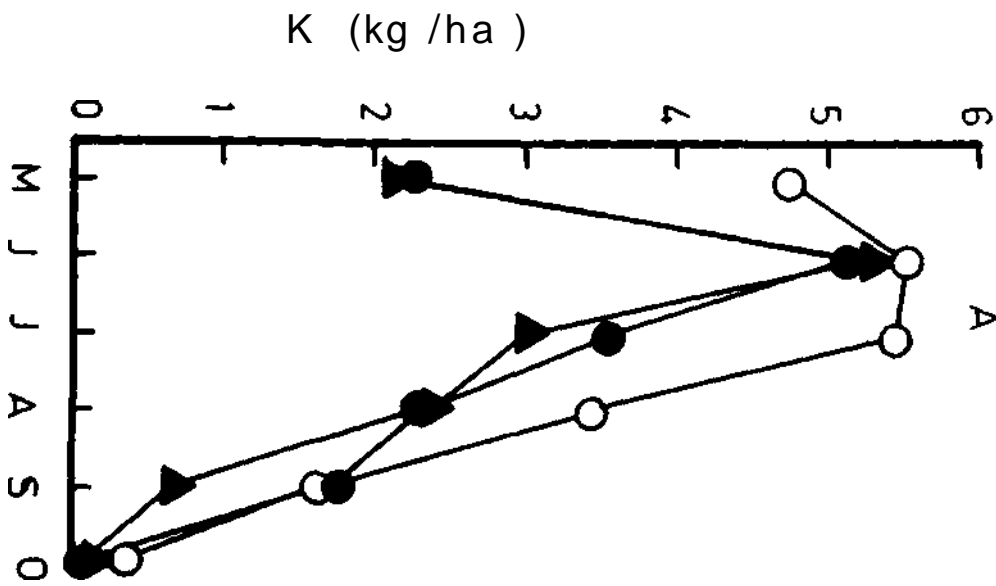


oa

o

V<sup>1</sup>  
«J1

Fig. 5.6. Monthly loss of potassium (A), calcium (B) and magnesium (C) in percolated water during the monsoon at the time of cropping after the burn in sites under 30 (•), 10 (O) and 5 (A) year jhum cycles.



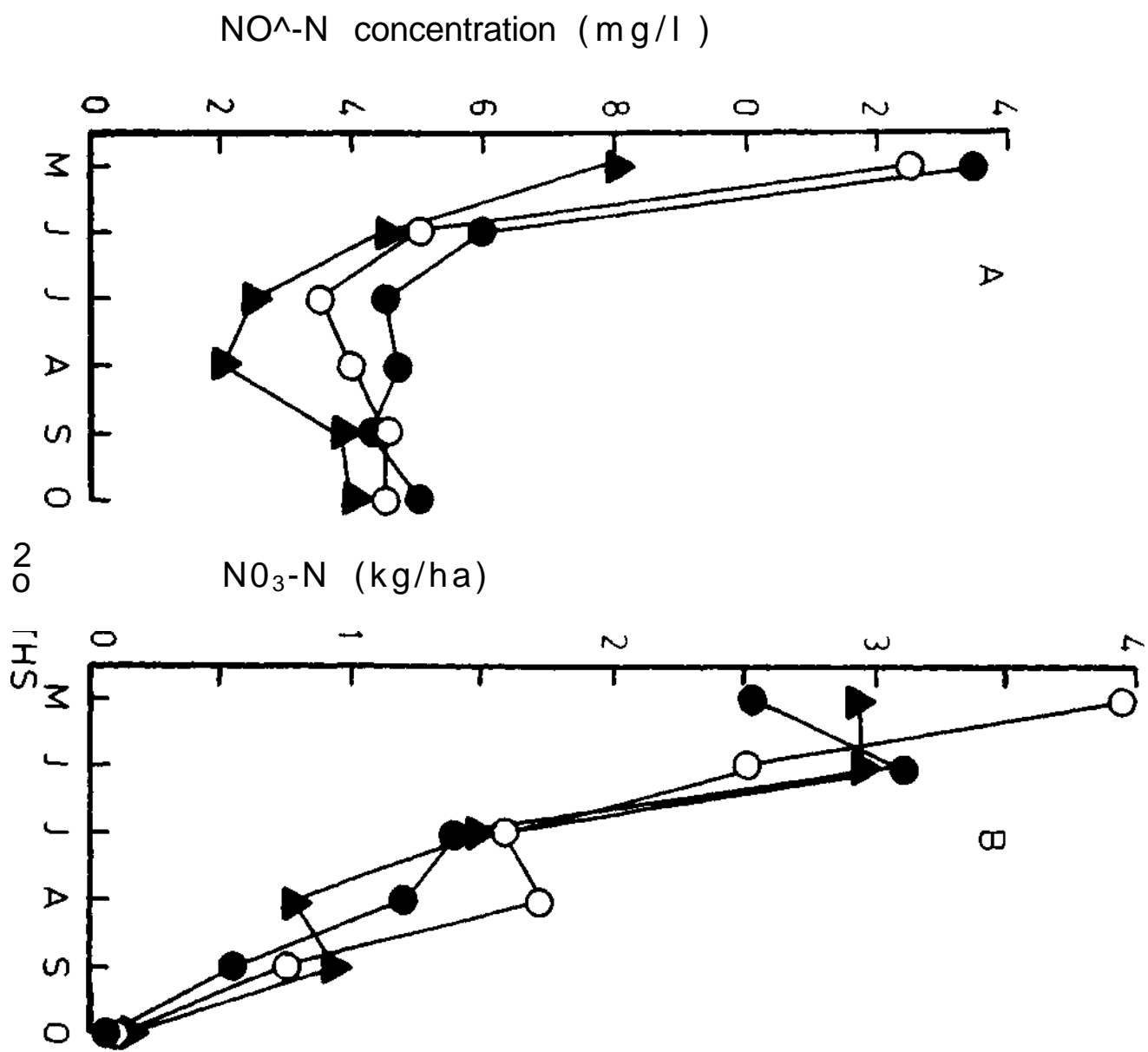
en  
en

Table 5.5.

Total loss of nutrients (kg/ha/yr) in percolated water in agro-ecosystem under various jhum cycles.

Element (kg/ha/yr)	T	Jhum cycle (yr)		
		30	10	5
Ga <sup>++</sup>	!	, 5.347 <i>J</i>	4*942	4.560
Mg <sup>++</sup>	j	2.528	2.116	2.267
<b>K</b> <sup>+</sup>	<b>i</b>	15.076	21.178 *	13.665
NO <sub>3</sub> -N	!	8.821	10.650	9.220
PO <sub>4</sub> -P	j	0.051	0.655	0.065

Fig. 5.7 A & B. Changes in concentration (A) and monthly loss (B) of  $\text{FO}_{\text{N}}$  in percolated water during the monsoon at the time of cropping after the burn in sites under 30 ( • ), 10 ( 0 ) and 5 ( A. ) year jhum cycles.



en

## ASS

(Fig. 5.7G). The total amount of  $P_{04}$ -P in infiltrated water peaked during June-July declining sharply on either side (Fig. 5.7D). The total loss of this nutrient during the monsoon period was minimum under a 30 year jhum cycle and increased with shortening of the jhum cycle (Table 5.5).

### Run-off and percolation losses in fallows:

The concentration of various cations and  $F_{03}$ -N and  $P_{04}$ -P in run-off and infiltrated water was markedly lower under 5 and 10 year fallows compared to the jhum agro-ecosystems described above. Thus the total loss of these nutrients in a 5 and 10 year fallows was also significantly low. From an agro-ecosystem under a 10 year cycle the losses through water were 7.8 - fold for calcium, 5.6 - fold for magnesium, 59.8 - fold for potassium, 15.4 - fold for  $NO_3$ -N and 19.6 - fold for  $P_{04}$ -P higher compared to a 10 year old fallow (Table 5.6).

## DISCUSSION

After clear-cutting and subsequent burning of the forest cover, the system loses its ability to hold the nutrients. A good proportion of the ash along with the nutrients is lost due to blow-off by strong winds

Fig. 5.7 C & D. Changes in concentration (C) and monthly loss (D) of  $\text{PO}_4\text{-P}$  in percolated water during the monsoon at the time of cropping after the burn in sites under 30 ( • ), 10 ( O ) and 5 ( A ) year jhum cycles.

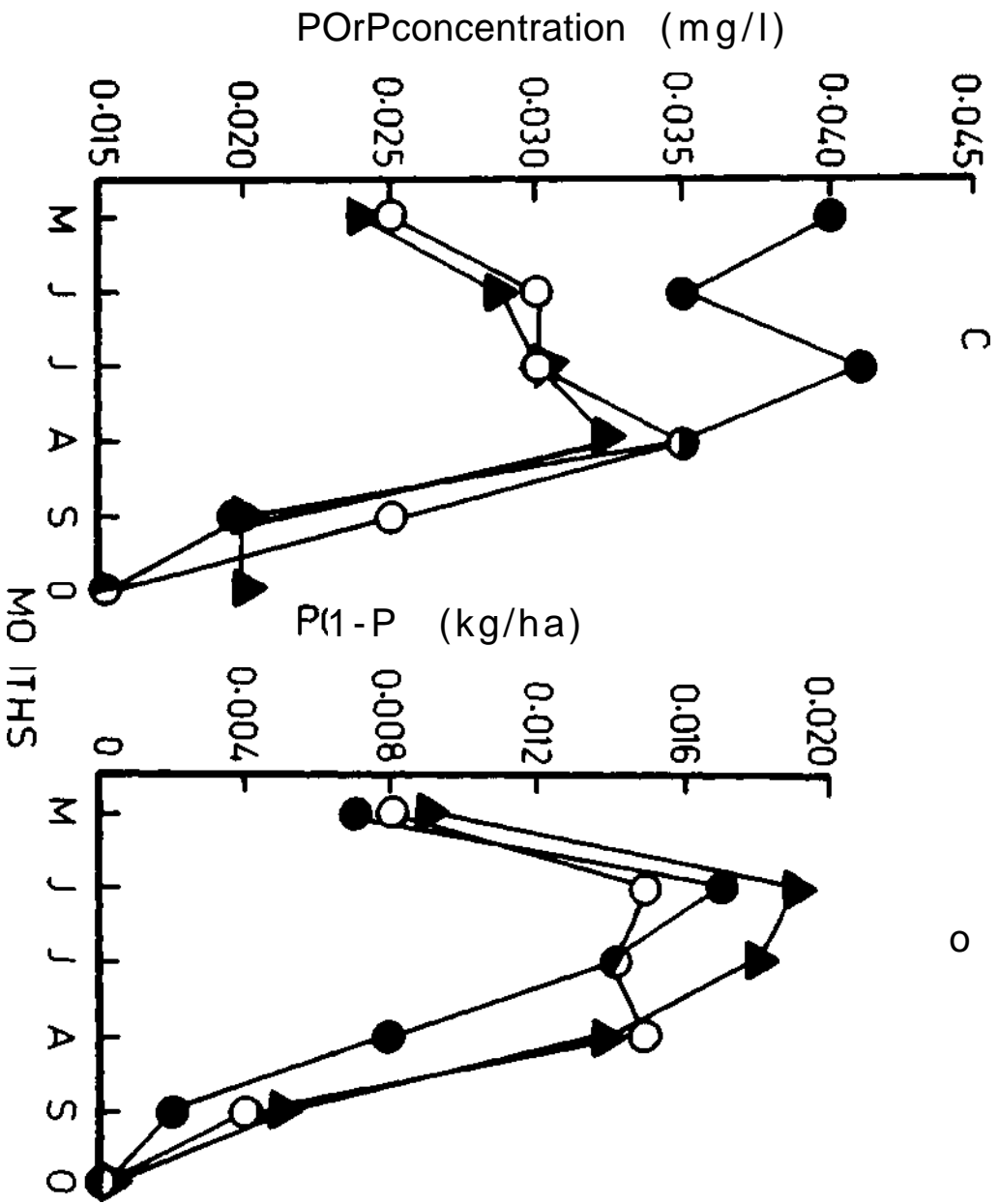


Table 5,6

Concentration and total loss of nutrients in run-off and percolated water under forested fallows.

Elements *	Concentration (mq/l)				Total loss (kq/ha/yr)			
	5 yr fallow		10 yr fallow		5 yr fallow		10 yr fallow	
	Run-off water	Percolated water	Run-off water	Percolated water	Run-off water	Percolatec water	Run-off ^water	Percolated water
Ca <sup>++</sup>	0.75	1.25	0.60	1.10	2.017	2.662	1.110	1.562
rig <sup>++</sup>	0.50	0.40	0.45	0.35	1.345	0.852	0.832	0.497
K <sup>+</sup>	0.35	0.25	0.90	0.15	0.941	0.532	1.665	0.213
NO - N	0.30	0.50	0.25	0.35	0.807	1.065	0.462	0.497
PO <sup>*</sup> -P <sub>4</sub>	0.05	0.01	0.03	0.01	0.134	0.021	0.055	0.014

## HO

during the dry months of March-April, immediately after the burn. In view of the large quantities of ash liberated under a 30 year jhum cycle, the losses also tend to be high, this being 4.2 times more than under a 5 year cycle. The ash released under a 30 year cycle had higher concentration and quantities of calcium due to the dicot trees that were slashed whereas under a 10 year cycle, the ash had a preponderance of potassium due to Dendrocalamus hamiltonii which was the main component of the slash and which has been shown to be a heavy accumulator of this nutrient (Ramakrishnan & Toky, unpublished). The higher concentration of phosphorus and magnesium in the ash released under a short jhum cycle may be related to the chemistry of the slash itself as much as potassium level under a 10 year cycle is much higher due to Dendrocalamus hamiltonii.

At the time of burn, heavy losses of at least some of the nutrients occur through volatilization. Large amount of carbon, nitrogen and sulphur are lost (Nye & Greenland, 1960; De Las Salas & Polster, 1976) due to volatilization during the burn. For phosphorus there are no obvious mechanisms of volatilization but

the matter has not been closely studied. Lloyd (1971) reported high loss of total phosphorus due to burning but Allen (1964) and Viro (1974) reported no losses on account of this. This is an aspect that has not been considered here.

Sizeable increase in run-off and percolated water after the burn is chiefly due to lack of plant cover which bind soil particles and contribute to utilization of water through uptake and canopy interception. Decrease in these losses during latter months of the monsoon is due to the development of a plant cover and also due to decrease in the intensity of the rainfall. The loss of water through run-off and percolation and the consequent sediment loss increased with the shortening of the jhum cycle. This may be partly related to poor physical characteristics of the soil and also due to poorer crop cover (Toky & Ramakrishnan, unpublished). The poorer quality of the soil under short jhum cycle may be due to frequent cropping after every 4-5 years. Further the weedy vegetational cover that develops during this period does not permit recovery of the soil quality and replacement of the soil lost due to sediment run-off. It may be mentioned here that under a short cycle of 4-5 years, the succession

is arrested with only weedy species like Eupatorium odpratum, and Imperata cylindrica as major components. It is particularly interesting to note that percolation losses of water is often greater than 50% of that lost through run-off which is due to the highly porous soil. From a conservational point of view, this implies that percolation losses may still be heavy even if erosion is checked through terracing of the land, as suggested by agricultural scientists, as an alternative to jhum.

Total concentration of cations in soil solution depends upon the total concentration of anions. A high level of nitrate ion due to increased 'biological activities' (Ahlgren & Ahlgren, 1965; Wells, 1971) balances a corresponding concentration of nutrient cations in the soil solution and therefore heavy losses through water occurs (Bormann et al, 1968; Lewis Jr. 1974). During the early months of the monsoon, heavy losses of cations through leaching were due to increase of nitrate ion in the leachate and also due to high volume of leachate collected in these months. Heavy run-off losses of cations and anions also occurred due to a large volume of surface water flow and a high concentration of nutrients in it. Later in the monsoon, actively growing crops and weeds reduced leaching and run-off

losses due to uptake of nutrients and reduction of water losses due to increased transpiration and canopy interception. These losses reported here for the year 1978 are an underestimate because during this year the monsoon was weak with an annual rainfall of 142 cm whereas the average annual for Burnihat is 220 cm per year.

After clear felling and burning, the loss of potassium through run-off and leaching was much higher as compared to other cations more conspicuously so under a 10 year cycle. This is due to the liberation of more potassium as the slash contained bamboo (Dendrocalamus hamiltonii) as a major component which is a heavy accumulator of potassium compared to other elements, as discussed above.

The biogeochemical recovery of a forested ecosystem depends upon the re-establishment of biotic regulation of ecosystem functions such as uptake of nutrients and water, storage of nutrients, mineralization and release of nutrients and erosion. Under jhum fallows, rapid recovery of these characteristics occurs due to favourable temperature, moisture and nutrient conditions of the soil. After one year of cropping, the nutrient status of the soil is reasonably good (Ramakrishnan & Toky, unpublished) and

the soil system has a variety of strategies for the development of vegetation, like rapid growth and expansion of stumps, rhizomes and root sprouts, and germination of buried and transported seeds. These factors along with favourable climatic conditions, help the system to recover quickly after deforestation. Eupatorium odoratum, a highly competitive weed species which comes immediately after the cultivated fields are abandoned and Imperata cylindrica and bamboo (Dendrocalamus hamiltonii)<sub>f</sub> which are highly rhizomatous species play a significant role in quick conservation of nutrients within the biomass in the 3<sup>rd</sup> fallows. Dendrocalamus hamiltonii has a remarkable potentiality to store potassium in the shoots (Ramakrishnan & Toky, unpublished). Thus in 10-20 year old fallows most of the potassium is conserved in the living biomass of this species and is released into the soil in older fallows, when it is replaced by other broad leaved tree species of secondary succession.

The loss of water, sediment and various nutrients are highly reduced in sites under 5 year and 10 year fallows. It may be accounted as due to interception of rain by the vegetation, low rate of nitrification, and low status of nutrients in the soil pool, due to rapid uptake by the fast developing plant cover. Within the first 5 to 10 year period

of succession, a rapid transfer of nutrients from the soil pool to vegetation compartment occurs, with the result that the soil becomes depleted of nutrients. The accumulation of elements in the biotic portion of the ecosystem during successional stages (Odum, 1969) reduces the losses through water. Ecosystems with nutrient saturated high exchange capacity soils would lose relatively more of their nutrients than those with nutrient unsaturated and/or low exchange capacity soils (Jordan, ~~et al~~, 1972) as is the case for lateritic soils that are sandy. For example the northern hard wood forest ecosystems (Likens, et al, 1977) in which a large percentage of the total ecosystem nutrients is in the soil in exchangeable form would lose a relatively large proportion of nutrients were the precipitation more acidic. In contrast, tropical rain forests would lose a relatively small proportion of nutrient, as in these forests most of the nutrients elements are tied up in the biomass (Odum, 1971; Jordan, ~~et al~~, 1972) and mineral soil has a very low nutrient content (Went & Stark, 1968).

In a five year fallow the total amount of nutrients taken up and stored in the living biomass and their subsequent release through litter fall and mineralization is

not sufficient to restore its chemical fertility (Ramakrishnan & Toky, unpublished). The physical conditions of the soil are also not improved within this period. The reduction of jhum cycle upto 4-5 years in most part of north-eastern India has adversely affected the vegetational cover as discussed elsewhere (Ramakrishnan, et al, 1980) and biogeochemical and hydrologic cycles, as discussed here.

#### SUMMARY

Subsequent to slash and burn of the forested fallow and during shifting agriculture (Jhum) in the north-eastern hill areas of India, the system loses its capacity to hold the nutrients. Various losses occur through wind blow off, ash and also through run-off and percolating water. The chemistry of the ash and run-off and percolating water is related to the length of the jhum cycle due to the type of vegetation that is slashed and burnt. The run-off and percolation losses of water and sediment during cropping increased with shortening of the jhum cycle. Since percolation losses are fairly high due to highly porous soil, terracing of land as suggested by some as an alternative to jhum is not an ecologically sound one. Drastic reduction in losses of sediment and nutrients occurred in a 5 and 10 year fallows.

The shortening of the jhum cycle to 4-5 years does not permit recovery of the soil fertility and has adversely affected the vegetational cover and the biogeochemical and hydrologic cycles.



CHAPTER 6

NUTRIENT CYCLING IN SUCCESSIONAL  
COMMUNITIES DEVELOPING AFTER SLASH  
AND BURN AGRICULTURE (JHUM).

NUTRIENT CYCLING IN A TROPICAL HILL REGION OF INDIA  
 AFTER SLASH AND BURN AGRICULTURE (JHUil)

#### INTRODUCTION

Slash and burn agriculture in the north-eastern hill region of India which is locally called 'Jhum' has a severe effect on mineral cycling, in that nutrients are released in a single large pulse and their availability exceeds the retention capacity of the ecosystem. Hence a large proportion is lost before they could be incorporated into the biomass (Toky & Ramakrishnan, unpublished). An important characteristic of the recovering forest ecosystem, after slash and burn agriculture, is its ability to store and recycle nutrients. The knowledge of nutrient cycling thus is essential for an understanding of the way in which the fertility lost during cropping is restored during the fallow period.

Data on the amount of nutrient stored, their rates of accumulation and cycling in successional forest communities is even more scanty than that for biomass and productivity. The work of Bartholomew *et al.*, (1953) attempts to study nutrient cycling and its changes in successional fallows upto 18 years of age at Tangambi who concluded that the storage capacity of leaves and litter gets saturated at an early stage, thereafter

the total storage increases more slowly and in the woody material only. According to him high amount of potassium accumulation occurs in the early stages due to the dominance of Musanga cecropioides.

Considerable information on nutrient cycling in temperate forests is available (Remezov et al, 1964; Rodin & Bazilevich, 1967; Whittaker et al, 1978) but relatively little is known about tropical and sub-tropical forests (Greenland & Kowal, 1960; Nye, 1961; Jordan & Kline, 1972; Golley et al, 1975). Though the information on tropical forests is quite limited, certain patterns are nevertheless suggested by these studies. Uptake and return of nutrients may be greater per year in tropical forests than in others and a larger proportion of the entire chemical inventory of the system may be held up in the vegetation (Rodin & Bazilevich, 1967).

The aim of the present study is to assess (i) the amount and rate at which nutrients are stored in the vegetation, (ii) the rate of transfer of nutrients from the vegetation to the soil through litterfall and the rate of uptake by the developing communities and (iii) the build up of the nutrient reserve in the soil pool; through successional communities upto 20 years after slash and burn agriculture

# no

(Jhum) in the lower elevations of the hill areas of Meghalaya in the north-eastern India.

The study was done at Burnihat which is located in the Khasi hills of Meghalaya at 26.0°N and 91.5°E. Here jhum is practised in its typical form by one of the tribes of Meghalaya namely the 'Garo'. The climate at Burnihat is hot and humid with an average rainfall of 220 cm. The climate could be divided into three distinct seasons. The dry and windy summer is from mid-February to May with an average maximum temperature of 33°C and a minimum temperature of 9°C. The rainy season extends from May to October. The mild winter with an average maximum temperature of 25°C and an average minimum temperature of 5°C extends from November to mid-February. This period is practically rainless except for a few winter showers. The angle of the slope varies from 20° to 40°. The soil is a sandy loam of lateritic origin with an average pH of 5.5 to 3.5.

## IVETKOJS 0i< STUDY

Methods used for estimating aboveground biomass, productivity and litter in jhum fallows are given in Chapter 3. Each category of plant samples was further sub-divided into leaves, branches, bole, etc. for biomass estimation and

chemical analysis, litter sampling was done at monthly intervals whereas plant sampling was done once at the peak of vegetative growing period during October.

Plant sampling, of dominant species was done separately for each species. All the minor species in the community were mixed together into a composite sample. However, the different compartments like leaves, branches and boles were analysed separately in each case. After separating into different categories according to species types and litter types, the litter collection done throughout the year were made into composite samples by thoroughly mixing them up.

Both plant and litter samples were ground to a fine powder and passed through a 0.5 mm sieve. Plant analysis was done following the procedures given by Allen (1971). Nitrogen

-hit

was determined by Kjeldahl method; total phosphorus was measured by dry ashing after saturating with  $Mg(NO_3)_2$  and measuring concentration in the ashed material calorimetrically by the molybdenum-blue method. Magnesium and calcium were analyzed by the EDTA titration method while potassium was estimated by the flame emission method after dissolving the ashed sample in dilute HCl. With the information on biomass and litterfall and their chemical concentrations, total chemical inventory of each compartment was computed.

Soil sampling was done once during the study period during March in each of the fallow, on the basis of a number of sub-samples representing the different micro-environmental conditions and topography. The sub-samples were thoroughly mixed into a composite sample. The soil was dried, ground and passed through 2 mm sieve and analysed for various elements following the procedures given by Allen (1974). Total nitrogen was determined by the Kjeldahl method. Magnesium and calcium were analysed by EDTA titration method while potassium was estimated by the flame emission method after extracting the exchangeable cations with 1M Ammonium acetate at pH 7. Available phosphorus was measured by the molybdenum-blue method, calorimetrically. Quantity of each element in the soil on a hectare basis was calculated upto a depth of 40 cm with the help of bulk density which was determined as 1.4 and 1.5 at 0-14 cm and 14-40 cm depths respectively.

While calculating the total inventory of bio-elements in the whole ecosystem, soil pool of total nitrogen, available phosphorus, potassium, calcium and magnesium upto a depth of 40 cm was added up the total quantities of bio-elements held up in the standing biomass during October which

is the peak period of vegetative growth. To this inventory, nutrients held in the litter compartment on the forest floor in October were added up.

For each compartment, turnover time was determined by dividing the quantity of each element present in the compartment by the yearly rate at which the element leaves that compartment, and the cycle time for each ecosystem is the sum of turnover times of all the compartments (Jordan & Kline, 1972). In the present study, only two major compartments namely soil and vegetation, were considered. Enrichment ratio for each stand was calculated as the ratio of element stock in the vegetation and the elemental uptake by it (Woodwell et al, 1975).

### RESULTS

An analysis of different nutrients in different compartments of the living and litter biomass showed that the leaves had higher concentrations compared to others and the bole had the least concentration. The concentration of nitrogen, phosphorus and potassium was much higher in the living biomass of branches and leaves than in the litter of their plant parts but, calcium and magnesium concentration did not show much difference. Level of calcium and magnesium in different compartments of dicot trees was higher compared

## M<sup>^</sup>

to bamboo (Dendrocalamus hamiltonii) and herbaceous species but bamboo had significantly greater concentration of potassium than in others. Shoots of herbaceous species showed markedly higher concentration of nitrogen and phosphorus than dicot tree and bamboo. Potassium concentration in the plant tissue, in general, was higher than of other elements in the case of all categories of plants (Fig. 6.1).

The total amount of nutrients stored in the above-ground living biomass increased with increase in age of the fallow upto 20 years, with maximum accumulation for potassium followed by nitrogen. Calcium and magnesium inventory was low with a ratio of 2.4 to 3.4 for potassium/calcium and 2.3 to 6.3 for potassium/magnesium in various fallows. Herbaceous species contributed 100% of the total nutrients in a 1 year regrowth, 96% in a 5 year fallow, and in older fallows their contribution was negligible. Older fallows of 10-20 years were dominated by bamboo (Dendrocalamus hamiltonii) and this species alone contributed 40 to 40% nitrogen, 44 to 49% phosphorus, 55 to 50% potassium, 17 to 20% calcium and 35 to 40% magnesium of the total output of nutrients. Contribution by dicot trees and shrubs increased between 5 and 20 year of fallow period

Fig. 6.1. Concentrations (^) of nutrients in various compartments of dicot trees and shrubs (A), bamboo (B) and herbs (C) in a 20 year fallow, and herbs (D) in a 5 year fallow.

I, represents the standard error of the mean\*

Striped column, nitrogen;  
stippled column, phosphorus; open column, potassium; hatched column, calcium; circled column, magnesium\*



# ns

with proportionally more calcium contribution than potassium in contrast to that by bamboo (Table 6.1),

Fig. 6.2 shows the pattern of distribution of the nutrients in boles branches and leaves compartments of the standing biomass. Boles of trees had maximum storage of nutrients followed by branches and leaves in older fallows of 10, 15 and 20 years. In a 1 year fallow, which was devoid of trees, the stem and branches of herbaceous species stored maximum amount of nutrients out of the total budget. However, the leaf compartment had greater proportion of nutrients in a 1 year fallow out of the total budget, compared to the older fallows. The same is true for a 5 year fallow except that some tree growth was there at this stage. While nutrients like potassium, calcium, magnesium and phosphorus were higher nutrients in the bole and branches, the proportion of nitrogen was more in the leaf tissue compared to other elements.

Rate of accumulation of nitrogen, phosphorus and magnesium followed a similar trend in that the rate decreased upto 10 year fallow period and increased sharply in older fallows upto 20 years. Rate of accumulation of calcium showed a steady increase upto a 20 year fallow but that for potassium increased upto a 15 year fallow

vegetation

Table 6.1  
Nutrient contents (kg/ha) in various compartments of aboveground living biomass in successional communities upto 20 years developed after slash and burn agriculture (jhum).

Category	Element (kg/ha)	Successional age (years)					
		1	5	10	15	20	
Dicot trees	N		26.161	110.056	185.428	292.381	
	P		3.164	12.817	22.283	35.647	
	Shrubs	K		55.916	217.931	387.352	624.854
		Ca		32.353	130.508	228.284	366.347
		Mg		13.111	54.863	93.357	148.016
Bamboo	N		5.817	82.406	153.153	196.073	
	P		0.843	12.121	21.884	28.524	
	K		23.042	323.727	589.061	753.708	
	Ca		2.188	31.686	56.161	73.971	
	Mg		2.368	33.366	61.258	78.342	
Herbs	N	30.669	111.454	1.387	0.626	0.558	
	P	4.974	15.607	0.168	0.078	0.070	
	K	35.281	109.680	1.168	0.548	0.488	
	Ca	13.680	45.327	0.517	0.238	0.212	
	Mg	15.437	50.392	0.566	0.261	0.233	

Pig. 6.2. Percentage distribution of nutrients in boles (A), branches (B) and leaves (C) of aboveground biomass in successional communities upto 80 years.

Stripped, column nitrogen; stippled column, phosphorus; open column, potassium; hatched column, calcium; circled column, magnesium.



# m

and decreased subsequently. Potassium showed the highest rate of accumulation (Table 6.2).

Table 6.3 presents the annual rate of uptake of elements into the aboveground biomass and their enrichment ratio. Rate of uptake of all the nutrients increased consistently as the successional communities developed upto 20 years. Potassium was taken up in large quantities followed by nitrogen and calcium; phosphorus showed the least uptake. The enrichment ratio for all the elements showed an increasing trend similar to the trend for uptake, upto the age of 20 years. The ratio was much higher for potassium and phosphorus indicating their faster rate of conservation in the aboveground biomass.

Total quantity of nitrogen in the soil pool upto a depth of 40 cm increased upto a 10 year fallow and stabilized at a low level in older fallows. Available phosphorus increased upto a 20 year fallow. Exchangeable potassium, calcium and magnesium started with a high level in the initial stages of fallow development after slash and burn agriculture, declined in the first few years and tended to improve in 15 and 20 year fallows. Maximum depletion in the initial fallows and enrichment in older fallows occurred for potassium in the soil pool (Table 6.4)

Table 6.2

Rate of accumulation of nutrients (kg/ha/yr) in above-ground living biomass in successional communities upto 20 years developed, after slash and burn agriculture (Jhum).

Time span (years)	<u>Rate of accumulation Ckg/ha/vr)</u>				
	N	P	K	Ca	Ig
0-1	18.219	3.978	28.641	9.945	11.536
1-5	15.380	2.854	30.337	11.804	8.957
5-10	13.836	1.348	69.059	15.529	5.186
10-15	24.123	3.337	81.107	22.556	11.724
15-20	25.087	3.579	75.674	28.504	12.499

Table 6.3  
 Rate of uptake of nutrients (kg/ha/yr) above ground biomass in  
 successional communities after slash and burn agriculture (Jhurn)

Time span (years)	Rate of Nutrients uptake (kg/ha/yr)				
	N	P	K	Ca	Mg
0-1	31.181 (0.98)	4.566 (1.08)	36.226 (0.97)	18.879 (0.72)	17.632 (0.87)
1-5	57.157 (2.50)	5.04E (3.89)	59.973 (3.14)	43.806 (1.82)	30.179 (2.18)
5-10	75.566 (2.56)	5.145 (4.85)	119.977 (4.52)	53.459 (3.04)	32.273 (2.75)
10-15	91.147 (3.70)	7.416 (5.96)	136.348 (7.16)	64.277 (4.42)	41.337 (3.74)
15-20	108.489 (4.50)	8.732 (7.35)	145.237 (9.49)	78.905 (5.58)	48.861 (4.63)

\* Annual uptake = Annual increase in nutrients in biomass + Annual nutrients return via litterfall. Values in parentheses are the enrichment ratios which are element stock/element uptake (Woodwell, Vittaker & Houghton, 1975).

Table 6.4

Total inventory of nutrients (kg/ha) in aboveground living biomass, litter and soil compartments of successional communities upto 20 years developed after slash and burn agriculture (Jhum).

Compartment "	Element (kg/ha)	Successional age (years)				
				10	15	20
Aboveground Biomass	N	31	143	194	339	489
	P	5	20	25	44	64
	K	35	189	543	977	1379
	Ca	14	80	163	249	476
	Mg	15	66	89	155	227
Soil (0-40cm)	F	9776	11098	12252	10551	10501
	P	11	8	19	23	27
	K	987	570	261	1182	1201
	Ca	1358	796	1037	1093	1080
	Mg	1300	1084	719	1199	1206
Litter present on soil in October	N	3.240	8.355	18.519	22.890	20.850
	P	0.088	0.547	1.177	1.019	1.030
	K	1.137	1.481	5.091	2.762	6.956
	Ca	1.786	4.800	11.379	8.344	18.608
	Mg	1.345	4.244	9.480	5.922	7.636
Total	N	9810.240	11,249.355	12,464.519	10,912.890	11,010.850
	P	16.088	28.547	45.177	70.019	92.030
	K	1023.137	760.481	809.091	2161.782	2586.956
	Ca	1373.786	880.800	1211.379	1350.344	1569.608
	Mg	1316.786	1154.244	817.480	1359.922	1440.636

Total inventory of nitrogen for the whole ecosystem peaked to a maximum in a 10 year fallow and declined on either side. Phosphorus showed an increase in the budget with increasing age of the fallow. A high cationic budget was present in the initial phase of succession, with minimum inventory in a 5-10 year fallow, and a subsequent increase upto 20 years. The proportion of different nutrients in the living biomass gradually increased with increase in the age of the fallow compared to the soil pool, this being more pronounced for phosphorus and potassium (Table 6.4).

Input through litterfall:

Annual return of nutrients through litterfall increased with the age of the fallow upto 20 years. Nitrogen followed by potassium and calcium contributed maximum quantity to the total budget. In a 1 year fallow, out of the total budget of 36.2 kg/ha all of it came through leaves. In a 5 year fallow, the contribution through twigs was maximum (18.170). This decreased with the age of the fallow so that in a 20 year forest, (but of the 24.8 kg/ha of nutrients in litter, 94.1% was through leaves and the rest through twigs. In general, nitrogen contribution by species other than bamboo was much higher. In older fallows where bamboo was a predominant component of the forest fallow, potassium

contribution by it equalled or even exceeded by that through all the other species put together. This was also true for phosphorus contribution by bamboo. However, calcium and magnesium contribution through bamboo litter was much low (Table 6.5),

The ratio of return of nutrients through litterfall to the annual uptake by the vegetation expressed as a percentage increased upto 5 years for potassium and 10 years for other nutrients after which it tended to stabilize at a slightly lower level. Maximum conservation of potassium followed by phosphorus occurred in the living biomass as the percentage return through litterfall was minimum in these two cases whereas nitrogen was one of the most mobile of all the nutrients (Fig. 6.3),

Nitrogen, calcium and magnesium showed decrease in turnover for soil compartment and increase in turnover time for vegetation compartment with the development of the communities through succession. Potassium also followed a similar pattern for vegetation compartment but for the soil the time period decreased to a minimum in a 10 year fallow but subsequently increased in older fallows. Though the pattern for phosphorus was not so well defined through

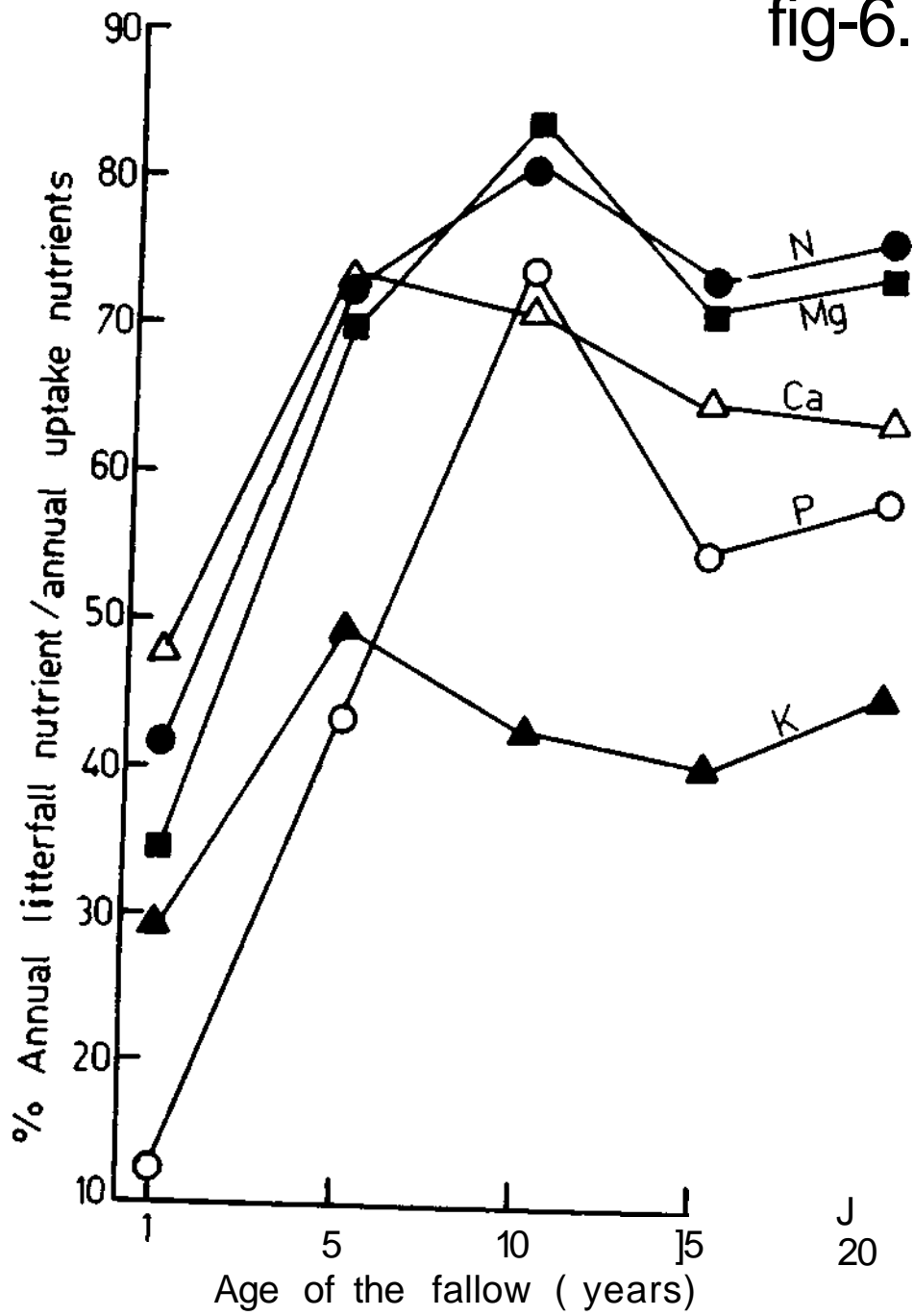
Table 6.5

Annual nutrient contents (kg/ha) of various components of litter in successional communities upto 20 years developed after slash and burn agriculture (Jharia)

Category	Elements Ckg/ha)	Successional age (years)				
		1	5	10	15	20
Leaves excluding bamboo	N	12.962	36.805	33.701	38.931	45.669
	P	0.588	1.671	1.530	1.768	2.074
	K	7.586	21.157	22.406	25.883	30.363
	Ca	8.836	24.441	27.549	31.824	37.332
	Mg	6.096	17.215	16.529	19.094	22.399
Bamboo leaves	N		10.989	26.079	26.582	35.316
	P		0.076	2.025	2.064	2.743
	K		19.909	23.990	24.453	32.487
	Ca		0.276	7.279	7.419	9.857
	Mg		0.336	8.862	9.033	12.000
Twigs excluding bamboo	N		3.984	1.386	0.798	0.949
	P		0.441	0.153	0.088	0.105
	K		7.570	2.633	1.516	1.803
	Ca		7.285	2.534	1.459	1.735
	Mg		3.671	1.277	0.735	0.874
Bamboo twigs	N			0.564	1.013	1.468
	P			0.089	0.159	0.231
	K			1.889	3.389	4.910
	Ca			0.568	1.019	1.477
	Mg			0.419	0.752	1.089
Total	N	12.962	41.777	61.730	67.324	83.402
	P	0.588	2.188	3.797	4.079	5.153
	K	7.585	29.636	50.918	55.241	69.563
	Ca	8.934	32.002	37.930	41.721	50.401
	Mg	6.096	21.222	27.087	29.613	36.362

Fig. 6.3. Annual return of nutrients through litter fall/Annual uptake expressed as a percentage for different successional fallows.

fig-6.3



successional communities, in older fallows the turnover time for both soil and vegetation was higher. Turnover time for calcium and magnesium in the soil compartment was much higher than that for potassium and phosphorus but the reverse pattern was true for the vegetation compartment, i.e. for nitrogen, the turnover time for soil compartment was maximum though this was much less for the vegetation compartment (Table 6.8)»

Cycle time for nitrogen was maximum in all the different fallows but decreased with the age of the fallow. The cycle time for cations was lower in older fallows compared to a 1 year fallow though in a 20 year fallow this tended to improve in all the cases. In case of phosphorus this improved in older fallows (Table 6.6),

#### DISCUSSION

In a comparative study of the nutrient concentration in the different compartment of the vegetation in a 20 year fallow, the level of nutrients in the litter compartment was in general found to be lower than that in the living biomass. This may partly be due to retranslocation of some of the nutrients like nitrogen, phosphorus and potassium into the living branches and boles

Table 6,6

**Turii\*Ter tines aad oycliag tiaes (years) ef amtrleats la suocessiemal  
cdioMumitles ufte 20 years dereloped after slasJa and Isara  
agriculture (Jku«)**

**Turnerer tiaes aad cycling times for nutrients (years)**

?«ll«w (years)	T.T.*		C.T.**		P		K		Ca		C.T.,»		C.T. Sell & Veg.		
	Sell	Veg.	Sell & Veg.	f.T. Sell	Veg,	C.T. Sell & Yeg.	O.T. Soil	Veg.	C.T. Soil & Veg.	a?.T. Sell	Veg.	Sell	Veg.	Sell & Veg.	
1	315.5	2.4	317.9	2.4	8.4	10.8	27.2	4.6	31.8	71.9	1.5	73.4	73.7	2.5	76.2
5	194.1	3.4	197.5	1.6	8.9	10.5	9.5	6.4	15.9	18.2	2.5	20.7	35.9	3.1	39.®
10	162.1	3.1	162.2	3.7	6.6	10.3	2.2	10.6	12.8	19.4	4.3	23.7	22.3	3.3	25.6
15	115.4	5.0	120.4	3.4	<b>10.8</b>	14*2	8.6	17.7	26.3	17.0	5.9	22.9	<b>29,0</b>	5.2	<b>w4.Z</b>
20	96.8	<b>0.3</b>	102 •6	3.1	12»S	15.6	8*3	19.8	28.1	13.7	9.4	23.1	25.7	6.2	31.9

\* T.T. 51 Tumeyer tiaes

\*• C.T. Qycling tiaes

before abscission and litterfall (Kramer & Kozlowski, 1960) and may also be due to leaching of nutrients before litterfall. It may be noted here that potassium which is more readily leachable (Nye & Greenland, 1960) has much lower concentrations in the litter compartment compared to the living biomass.

In the living biomass, among the cations, the concentration of potassium was much higher in a 20 year fallow, this being more obvious in the case of bamboo, Dendrocalamus

hamiltonii\* Apart from the fact that in early successional communities has been shown to be a more predominant element compared to calcium, with a reverse tendency in mature forests (Tergas, 1965; Snedaker & Gamble, 1969; Golley et al, 1975), particularly higher levels of potassium compared to calcium in bamboo is also due to the fast accumulation of this nutrient by this species which is an important component of the early fallows of secondary succession. This is more obvious when the total quantity of potassium held in the living biomass of a single species of bamboo in a 15 or 20 year fallow is compared with that held in all the dicot trees and shrubs present.

With the development of secondary vegetation, the nutrient reserve in the living biomass increased **upto**

20 years due to a linear increase in biomass with age (Toky & Ramakrishnan, unpublished). Because of the higher concentration of potassium in bamboo (Dendrocalamus hamiltonii) and the larger biomass contributed by this species, potassium is more abundant than calcium and magnesium. The high enrichment ratio for potassium in older fallows of 10-20 years indicates maximum conservation of this nutrient in the living biomass. A similar observation where Musanga oecropioides in the early successional forests of Belgian Congo selectively takes up potassium was shown by Bartholomew <sup>et al</sup>, (1953) though the Inventory for potassium in their study was much lower than in a 20 year fallow in the present study. It may be noted here that upto 10 years of fallow period when bamboo is not yet a major component of the vegetation, the enrichment ratio for phosphorus was more than for other elements indicating conservation of this nutrient in the living biomass. For calcium and magnesium, annual uptake and enrichment ratio was much higher in older fallows probably due to rapid growth of dicot trees at this stage. Greenland & Kowal (1950) reported almost three times more calcium than potassium in the aboveground biomass in a 40 year old forest in Ghana due to faster accumulation of the former in mature dicot trees.

All the nutrients, except nitrogen, were generally higher in a 1 year fallow due to rapid release due to slash and burn. The rapid decline in nutrients in the soil in a 5 or 10 year fallow is due to depletion by rapidly developing vegetation. Release of nutrients into the soil pool starts after 10 years of regrowth when there is a gradual build up of nutrients in the soil compartment. For nitrogen, on the other hand, initially not only is it lost due to burning of slash but the fixation of soil nitrogen may also adversely be affected due to burn. However, soon after the burn, microbial activity is shown to increase rapidly partly due to micro-environmental changes in the soil (Moore & Jaiyebo 1963; Ahlgren & Ahlgren, 1965) and also due to removal of allelopathic effects (Smith *et al*, 1968; Rice, 1974) so that nitrogen build up continues upto 10 year fallow period followed by a decline in subsequent years probably due to absorption by the developing community. Similar observations are also available for 'Lua' forest fallow system of shifting agriculture in Thailand (Zinke *et al*, 1978).

The return of nutrients through litterfall increased with the age of the fallow upto 20 years which is a function of the linear increase in the litterfall with the age

of the fallow (Toky & Ramakrishnan, unpublished). Higher quantity of potassium and lower quantities of other elements are returned annually as compared to the values reported by Ewel (1976) for successional fallows upto 14 years in Guatemala. This is due to the high levels of potassium compared to others in the predominant bamboo litter, as already discussed.

While the turnover time of all nutrients in the soil tended to decrease, that of the vegetation increased. This is to be expected because of the marked increase in uptake by the developing vegetation and the increased storage in the living compartment which is proportionately higher than the rate of release through litter.

Cycling time, in general, tended to decrease with increase in the age of the fallow / except for phosphorus, potassium showing a tendency for decrease upto 10 years followed by an increase in 15 and 20 year fallows. Cycling times for elements in ecosystems are influenced primarily by rates of elemental uptake and release by the plants. Phosphorus and potassium having minimum cycling times compared to other elements, show their fast rate of turnover within the ecosystem. The cycling times for various elements in the successional fallow vs calculated during the present

study are much less than the values reported for mature forests. Golley <sup>et al</sup> (1975) reported turnover times for phosphorus, potassium and calcium in mature forests of Panama • more than 100-200 years. The values in the present study for calcium turnover are in the range reported for temperate forests by Jordan & Kline (1972) but much higher than that reported for mature tropical forests. However, since the cycle time decreases with the age of the fallow, it may reach a comparable level in more mature forests of the area.

Mineral cycling varies according to the nutrient supply to the system and the time available for the system to develop on the site. For example, the soil in certain Amazonian forests (Stark 1971 a,b; Klinge & Rodrigues 1968 a, b) are podsoils which contain low quantities of nutrients and have low exchange capacity. As a consequence, concentration of nutrients in plants are much greater than in the soil and the elements released from the litter are rapidly taken up by the vegetation. This Amazonian case has led Stark (1971a) to propose a direct transport of nutrients by mycorrhiza from the dead organic matter to the living plant roots. In such a case cutting and burn will

destroy the mycorrhizal connection and the recovery of the system may take a much longer time compared to other systems. The studies from CMS laboratory, as yet unpublished, indicate that mycorrhizal development in plants of jhum fallows may be more extensive than suspected. The significance of this in nutrient cycling in Jhum fallows may prove to be interesting.

After a complete destruction of nutrient cycling at the time of slash and burn agriculture, the system recovers rapidly through quick succession and potassium which is one of the important nutrients which is also highly susceptible to leaching and run-off losses in the early phase of regrowth is rapidly conserved in the living biomass through bamboo. As this process of conservation progresses steadily during the first 20 years or so of the developing community, any disturbance at short time intervals as in the short jhum cycle of 3-5 years as in common now is likely to adversely affect the nutrient conservation by the system.

#### SUMMARY

Accumulation of bioelements, their rate of uptake and release through litterfall were measured in successional stands upto 20 years. Concentration of nitrogen, phosphorus and potassium was higher in living biomass than in the litter.

Dicot trees were found to be rich in calcium, bamboo (*Dendrocalamus aamiltonii*) in potassium and herbaceous species in phosphorus. The total inventory of bioelement increased linearly with increase in the age of the fallow and attained a maximum level of 489 kg nitrogen, 64 kg phosphorus, 1379 kg potassium, 440 kg calcium and 226 kg magnesium in a 20 year fallow. In this fallow 50 to 73% of the various elements of Dudgeon were allocated to the bole compartment. Potassium was the most abundant element followed by nitrogen. In fallows of 10 to 20 years, bamboo alone contributed 40 to 45% nitrogen, 14 to 49% phosphorus, 54 to 60% potassium, 16 to 19% calcium and 34 to 39% magnesium of the total budget. Maximum annual rate of accumulation of nitrogen (25.087 kg/ha) occurred in 15-20 year, phosphorus (3.978 kg/ha) in 1-year, potassium (81.107 kg/ha) in 10-15 year, calcium (28.004 kg/ha) and magnesium (12.499 kg/ha) in 15-20 year fallows. Potassium showed the highest rate of accumulation and it was 1.3 to 3.3-fold higher than that of calcium and magnesium collectively. Annual rate of nutrient uptake increased consistently with the age attaining a maximum rate between 15-20 years. The enrichment ratio was maximum for phosphorus and potassium indicating their fast rate of conservation in the standing biomass. Maximum depletion of soil nutrient

pool occurred between 5-10 year of growth period. Annual return of nutrients through litterfall increased with the age of the fallow showing maximum return in a 20 year fallow.

## GENERAL CONSIDERATIONS AND CONCLUSIONS

#### &EHEEAL CONSIDERATIONS AND CONCLUSIONS

In the north-eastern hill regions of India, the practice of slash and burn agriculture (Jhum) is a source of support for |.6 million tribal population. It is widely spread in Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Nagaland, Tripura and some parts of Assam over an area of 0.327 million hectares (Mukurjee, 1975). During the last twenty years, major socio-political, organization and administrative changes have taken place in this region. The population of these hilly states also increased slowly upto 1951 but increased sharply between 1951 to 1971. Thus in Meghalaya, to take an example, the decinial growth rate between 1900 to 1951 increased at the rate of 7.3<sup>^</sup> to 15.65<sup>^</sup> where during the following 2 decades it showed a decinial growth rate of 26<sup>^</sup> and 32<sup>^</sup>.

The jhum cycle previously was spread over 20-30 years, however, under present conditions of high population densities and reduced acreage, the cycle may be often as short as 4-5 years. Shorter cycles have adversely affected the quality of the environment both in terms of soil fertility as well as vegetational cover. The take over of jhum fallows by weedy colonizers like Eupatorium odoratum, Imperata

cylindrica. Mikanla maerantha. Saccharum spontaneum. Borrerla hispidaf etc. under short cycles has resulted in rapid deterioration in the environment. Succession has been arrested indefinitely at this pioneer stage. The aggressive weeds (Eupatorium odoratum) have either a high seed production or have extensive underground rhizomes (Imperata cylindrica) and cause a serious problem during the cropping period. Seduction in acreage is also related to the land being rendered useless for cultivation due to such a take over by weeds\*

When the cycle is short, hazards of erosion are considerable even though the land is colonized by weedy species and the likelihood of accidental spread of fire is increased because of the high susceptibility of Imperata cylindrica and other weedy species. Damage to the ecosystem could best be exemplified by an extreme exsuaple of impact of slash and burn agriculture at Cherrapunji. It is well known for being one of the highest rainfall regions of the world. The annual rainfall exceeds 1150 cm and an above average year may bring as much as 2250 cm, recorded during 1974. Most of this rainfall comes between May and September. Inspite of high rainfall, one is struck by the general barrenness of the landscape. A few xerophytic grass species

of Chrysothamnus, Cymbopogon, Eragrostis, Panicum and Paspalum survive in the thin layer of soil and rock crevices. However, Cherrapunji and its surrounding areas have patches of relict forests in the form of sacred grooves with rich species diversity. These areas contrast dramatically with the largely degraded landscape. These sacred grooves at Mawsmai at Cherrapunji have (faucibus spp., Castanopsis spp., Schima wallichii with a large number of shrubs like Photinia, Briobotrychium and ^numa.\* An obvious conclusion is that these forest were destroyed over a period of time, possibly through jhum cultivation. The evidence for this conclusion is two-fold (I) the local people practise jhum and (II) Jhum fields are extensive in the forested areas around Cherrapunji. In any case, due to damage to the ecosystem, there is scarcely any vegetational cover to hold the soil and there is no soil to support a forest. Similar is the case in many areas around Shillong.

Exotic weeds as mentioned earlier have created a serious problem in weed control due to rapid spread under a short jhum cycle. This has resulted in the rapid depletion of the germplasm, because of drastic changes in micro-climate and other elements of the habitat. Many orchid species of Dendrobium, Cymbidium and Vanda are on the endangered list

of plant species. Many timber yielding species which come late in the successional seres, have been eliminated due to shortening of the jhum cycles. Many endemic species, for example, Neoenthesls khasianum (pitcher plant) are threatened.

The forested areas in north-eastern hill region of India ensured the survival of a rich mammalian fauna. In fact more than 50% of the total number of mammalian genera known from the Indian sub-continent are represented in this region. Because of destruction of forest, chiefly due to jhum cultivation, the habitati of these animals have been damaged. A large number of species once distributed over large areas in this region are now on the list of protected species, e.g., eluded leopard (Neofelis nebulosa), golden cat (Pelis temmincki), leopard cat (Fells bengalensis), tiger (Panthera tigris), wild buffalo (Bubalus babalis), etc.

Under conditions of vast forest resources and sparse population, slash and burn agriculture (Jhum) would be in harmony with the environment as the labour of clearing, crop planting and weeding in relation to the size of the harvest is low and nutrient build up through forests would be sufficient to sustain agriculture without any need for other forms of nutrient inputs. From an energetic point

of view too, as evident from this study, the system could be considered as efficient as the output/input ratio may be as high as 43.50 for a 30 year jhum cycle as against a comparatively low value obtained under terrace cultivation (6.02) as seen from the present study. The only source of energy required for jhum is manpower which is cheap. The farmers are able to get all the diverse requirements of life from the mixed crops and from the forests.

The maintenance of crop yield is possible only when the jhum cycle is sufficient<sup>^</sup>; long; longer than 10 years as shown by the present study; In the shorter jhum cycles of 4-5 years, the yield particularly of grain and seed crops is drastically reduced. 5 year fallow period is not sufficient to replenish the soil with organic carbon, nitrogen, phosphorus and cations to the desired levels. Early regrowth of forests upto 5 year, depletes the soil with cations as heavy uptake of nutrients takes place at this stage due to the fast growing vegetation and it is not until after 10-20 years is there an enrichment of the soil. Bamboo (Dendro calamus hamiltonii) which is an important species in quick conservation of potassium after slash and burn agriculture dominates the fallows of 10-20 years age. Seduction in the jhum cycle adversely affects bamboo regeneration and potassium economy of the system.

Replacement of jhum by intensive agricultural practices is probably not a realistic solution to this problem. Terracing the land as suggested by some scientists is likely to create more problems than it would solve. Terracing and weeding are very expensive to which may be added the cost of fertilizers which would be one of the major inputs to sustain agriculture. Apart from the cost factor, the efficiency of utilization of fertilizers is also likely to be low as the soil is extensively loose, thin and porous, This would result in heavy infiltration losses if not surface run-off, as our studies show that infiltration losses could be very heavy. Further, under conditions that favour fast decomposition of litter and humus the system would also need heavy input of organic manure in order to maintain good physical conditions of the soil. It may also be noted that much of the losses from hill agro-ecosystem, imder crreal cultivation, occur during the early phase when crop cover is not yet available or at the time of harvest when the soil is disturbed.

The economy of the region should be developed with emphasis on horticultural crops like orange, banana, pineapple and various temperate fruits which could be introduced with success. Plantation crops like tea, coffee, cocoa and rubber

some of which have been tried successfully should also be encouraged.

Thus, keeping in view the climate, soil type and the topography of the hills, it may be desirable to keep cereal cultivation in any form to a minimum and encourage horticulture, other perennial crops, animal husbandry and tree plantation. These would cause less damage to the environment. One may go so far as suggesting importing grains into this region. In relation to the Indian sub-continent the geographical positioning of the Himalayas and other extension ranges like the hills of the north-east, is unique. We cannot afford to significant alteration because all major river systems originate from these mountains and drain into the northern plains of the country. Therefore, any damage to the ecosystem of these mountains would have repercussions over a large area of the plain (Record of floods in the Ganga basin in 1978 was related to extensive deforestation in the Himalayas). The repercussions might be; floods, deposition of silt, or major changes in the climate of the sub-continent.

LITERADUSE CITED

## LITERATURE CITED

- Ahlgren, I.P. & Ahlgren, C.E. (1965). Effects of prescribed burning on soil aieroorganisms in a Minnesota jack pine forest. *Ecology* 46, 304-310.
- Aha, P. (1958). Begrowth and swamp vegetation in the western fprest areas of Ghana. *J. West Afrio. Sei. Ass.* 4, 163-173.
- Allen, S.B. (1964). Chemical aspects of heather burning. *J. Appl. Ecol.* 1, 347-367»
- Allen, S.E. (Ed.) (1974). *Chemical Analysis of Ecological Materials.* Blaokwell Scientific Publ. Oxford.
- Anthony, K\*R.M. & Willimott, S.G. (1956). A study of soil fertility in Zandeland. *Bap. J. Expt. Agric.* 24, 75-88.
- Aurora, G.S., Billorey, fi.K., Patton, A. and l^rchiang, P. (1977). *Socio-economic Impact of Shifting Cultivation Control Schemes in North-Eastern Begion.* Bept. Sociol. and Anthropol., Vorth-Eastern Hill Univ., Shillong (Mimeographed).

- Bartholomew, W.Y., Meyer, J. & Laudelot, H.E. (1953).**  
**Mineral nutrient immobilization under forest**  
**and grass fallow in the Tangambi (Belgian**  
**Congo) Region. L\*Institut national pour**  
**L\*etude Agronomique du Congo Beige Ser. Sei.**  
**Ho. 57, Brussels\***
- Bedard, P«W. (1958). Heconnnaissance, classification and**  
**mapping of Philippine forests. Study of Tropical**  
**Vegetation, pp. 49-53. Proc. Kandy ^mposixim,**  
**UHESCO.**
- Bernhard, P. (1970). Etude de la litiere et de la**  
**Contribution au cycle des elements minerauz**  
**en for^t ombrophile de Cote-d'Ivoire. Oecologia.**  
**PI. 5, 247-66.**
- Birch, H.P. & Priend, M-T. (1956). The organic matter  
 and nitrogen status of east African soils.  
 J. Soil Sci. 7, 156-167.
- Bormann, P.H., Likens, G.E., Pisher, D.W. & Pierce, E.S.  
 (1968). Nutrient loss accelerated by clear-  
 cutting of a forested ecosystem. Science 159,  
 882-884.
- Bormann, P.H« & Likens, Gr.E. (1979). Pattern and Process  
 in a Porested Ecosystem. Springer-Verlag, Hew York.

- Borthakur, D.N., Singh, A., Awasthi, H.P, & Hai, R.N. (1978). Shifting cultivation in the north-eastern region. In: Resources, Development and Environment in the Himalayan Region, pp.330-342. Dept. Sci. & Tech., Govt. of India.
- Bray, J.R. & Gorham, B. (1964). Litter production in forests of the world. *Adv. ecol. Res.* 2, 101-57.
- Buekman, H.O- & Brady, N.G. (1960). *The Nature and Properties of Soils.* McMillan Co., New York.
- Carneiro, R.I. (1960). Slash and burn agriculture: A closer look at its implications for settlement patterns. In: *Men and Cultures* (Ed. by A.P.O. Wallace), pp. 229-234. Philadelphia.
- Clayton, W.D. (1958). Secondary vegetation and transition to savanna near Ibadan, Nigeria. *J.Ecol.*46, 217-238.
- Conklin, H.C. (1957). *Hanunoo Agriculture.* P.A.O. Forestry Development paper No. 12. P.A.O., Rome.
- Cook, O.P. (1921). Milpa agriculture, a primitive tropical system. *Annual Report of Smithsonian Institution*, 1919, pp. 307-326. Washington, D.C.

- Coulter, J.K. (1950). Organic matter in Malayan soils: A preliminary study of the organic matter content in soils under virgin jungle, forest plantations and abandoned cultivated land. *Malayan Perseer* 13, 189-202.
- Cutting, C.V., Good, R.A., Brown, P. & Mbrase, H.B.(1959). Assessment of fertility status and the maintenance of productivity of soils in Byasaland. Paper Fo.69. Third Inter-Afr. Soils Conf. Dalaba.
- De Las Salas, G. & Polster, H. (1976). Bioelement loss on clearing a tropical rain forest, *furrialba* 26, 179-186.
- Dobby, S.H.Cr. (1950). *South-east Asia*. London.
- Dommercluea, Y. (1963). Les cycles biogéochimiques des éléments minéraux dans les formations tropicales. *Bois et forêts des tropiques* 87, 10-25.
- Edwards, P.J-(1977). Studies of mineral cycling in a Montane Bani forest in Guinea II. The production and disappearance of litter. *J.Ecol*, 65, 971-992.
- Ekwall, E, (1955). 'Slash-and-burn'cultivation: A contribution to anthropological terminology. *Man* 55, 135-136<

- Baerson, S.A. (1953). A preliminary survey of the ailpa system of maize culture as practised by the Maya Indians of the northern part of the Yucatan Peninsula. *Inn. Missouri Bot. Gard.* 40, 51-62.
- Ewel, J.J. (1976). Litterfall and leaf decomposition in a tropical forest succession in eastern Guatemala. *J.Ecol.* 64, 293-308.
- Freeman, J.D. (1955). Iban Agriculture. A report on the shifting cultivation of hill rice by the Iban of Sarawak. H.M.S.O., London.
- Golley, P.B., Me Ginnis, J-T. & Clements, R.G. (1969). Pinal report, terrestrial ecology. Battelle Memorial Instit., I.O.C.S. Mem. BMI-26. 70p.
- Golley, P.B., Me Ginnis, J.T., Clements, E.G., Child, G.I. & Buever, M.J.(1975). Mineral Cycling in a Tropical Moist Forest Ecosystem. Univ. of Georgia Press, Athens.
- Gopalan, C.B., Bama Sastri, 7. & Balasubramanlan, S.C.(1976). Nutritional value of Indian Foods. Nat. Inst. Nutrition, Hyderabad.
- Gourou, P. (1953). The Tropical World (Trans, by E.D.laborde) London.
- Greenland, B.J. & Kowal, J.M.L.(1960). Nutrient content of the moist tropical forest of Ghana. *Pl. and Soil* 12, 154-74.

- Griffith, G. (1949). Fertility problems in Uganda. *Comflonw. Bur. Soil Sci. !Eech. CoBmmn. 9o. 46*, pp. 160-164.
- Grime, J.P. (1974). Tegetation classification by reference to strategies. *Bature 250*, 26-31.
- Hareombe, P-A. (1973). Futrient cycling in secondary plant succession in humid tropical forest region (Turrialba, Costa Hiea). Ph.D. Thesis, Tale University.
- Harper, J.L. & White, J. (1974). The demography of plants. *Ann. Hev. Ecol. A Siystemat. 5*, 419-483.
- Harroy, J.P. (1949). *Afrique, Terre qui Meurt*. Brussels.
- Hayashi, I & Bumata, M, (1968). Ecology of pioneer species of early stages in secondary succession II. The seed production. *The Botanical Magazine, Tokyo 81*, 55-66.
- Jenny, H. & Hay Ohaudhuri, S.P. (1960). Effect of Climate and Cultivation on Mtrogen and Organic Matter Besomrees in Indian Soils. *Ind. Counc. Agrio. Hes., Hew Bel^i*.
- Jha, M»l., Pande, P. & Pathak, T.C. (1979). Studies on the changes in the physio-chemical properties of Tripura soils as a result of jhumming. *Indian forester 105*, 436-443.

- Joachim, A.W.R. & Kandiah, S. (1948). *The effect of shifting (Chena) cultivation and subsequent regeneration of vegetation on soil composition and structure.* Trop. Agrist. 104, 3-11.
- Jordan, C.P. (1971). *Productivity of a tropical rain forest and its relation to a world pattern of energy storage.* J. Ecol. 59, 127-142.
- Jordan, C.F. & Kline, J.R. (1972). *Mineral Cycling s Some basic concepts and their application in a tropical rain forest.* Ann. Bev. Scol. & S<sup>^</sup>stemat. 3, 33-50.
- Jordan, C.F., Kline, J.R. & Sasser, D.S<sup>^</sup>(1972). *Relative stability of mineral cycles in forest ecosystems.* Am. Natur, 106, 237-253.
- Juo, A.S.R. & Lal, R. (1977). *The effect of fallow and continuous cultivation on the chemical and physical properties of an alfisol in western Nigeria. Pt. and soil 47, 567-584.*
- Kellman, M.C.(1970). *Secondary plant succession in tropical montane Mindanao.* Dept. Biogeogr\* Geomorph. Publ. BG/2 Australian National Univ., Canberra, Australia.
- Kenoyer, L.A.(1928). *General and successional ecology of the lower tropical rain-forest of Barro Colorado Island, Panama, Ecology 10, 201-222.*

- Kershaw, E.A. (1973). Quantitative and Synaiaie Plant Ecology. Edward Arnold, London\*
- Klinge, H. & Hodrigues, W.A. (1968a). Litter production in an area of Amazonian Terra Pirme forest. Part I. Litter fall, organic carbon and total nitrogen contents of litter. Amazonia 1, 287-302.
- Zlinge, H. & Hodrigues, W.A. (1968b). Litter production in an area of Aazonian Terra Pirae forest. Part II. Mineral nutrient content of the litter. Amazonia 1, 303-310.
- Kramer, P.J. & Kozlowski, T.T. (1960). Physiology of Trees. McGraw-Hill Book Co. Inc., New York.
- Laudelot, H. & Meyer, J. (1954). Les cycles d\*elements min^raux et de matiere organique en for^t equatoriale congolaise. Trans. Fifth Int. Cong. Soil Sci. (Comm.II), 267-72.
- Lawson, G.W., Armstrong-Mensah, K.O. & Hall, J. (1970). A catena in a tropical moist semi-deciduous forest near kadi, Ghana, J.Ecol. 58, 371-398.
- Lewis, Jr., W.M. (1974). Effects of fire on nutrients movement in a south Carolina pine forest. Ecology 55, 1120-1127.

- Likens, G.E., Bormann, F.H., Pierce, R.S., Eaton, J-S. & Johnson, N.M. (1977). Biogeochemistry of a Forested Ecosystem. Springer-Verlag, Hew York\*
- Likena, Gr.B., Bormann, P.H., Pierce, R. S. & Reiners, W.A. (1978). Recovery of a deforested ecosystem. Science 199, 492-496.
- Lloyd, P»S. (1971). Effects of fire on the chemical status of herbaceous communities of the Derbyshire Dales. J. Ecol. 59, 261-273.
- Lugo, A. (1973). Tropical ecosystem structure and function. INs Fragile Ecosystems (Ed. by Edward G. Parnworth & P.B. Golley), pp.67-111. Springer-Yerlag, Berlin.
- Margalef, R. (1958a). Temporal succession and spatial heterogeneity in Phytoplankton. In: Perspectives in Marine Biology (Ed. by A.A.Buzzati & B.T. Traberso), pp. 323-349. Univ. California Press, Los Angels.
- Margalef, R. (1958b). Information theory in ecology. Gen. §yst. 3, 36-71. (Translated by W.Hall from La teoria de la informaeion en ecologia 1957. Mem. R. Acad. Cienc. Artes Bare. 32, 373-449.)
- Margalef, H. (1961). Communication of structure in planktonic populations. Limnol. Oceanogr. 6, 124-128.

- Margalef, R. (1968). Perspectives in Ecological Theory. Univ. Chicago Press, Chicago.
- Margalef, R. (1969). Diversity and stability : A practical proposal and a model of interdependence. Inj Diversity and Stability in Ecological Systems (Ed. by Gr.M. Woodwell & H.H. Smith), pp. 35-37. Brookhaven Symposia in Biology, Ho. 22.
- Marks, P.L. (1974). The role of pine cherry (Prunus Pensylani»a L.) in the maintenance of stability in northern hardwood ecosystems. Ecol. Monogr. 44, 73-88.
- May, H.M. (1973). Stability and Complexity in M<Gdel Ecosystems. Princeton Univ. Press, Princeton.
- McFaughton, S.J. (1967). Relationship among functional properties of Californian grassland. Nature (London) 216, 168-169,
- Melili®, d.M. (1977). Mineralization of Nitrogen in Northern Forest Ecosystems. Ph.D. Thesis. Yale Univ., New Haven, G.T.
- Mellinger, M.V. & McNaughton, S.J. (1975). Structure and function of suceessional vascular plant communities in Central New York. Ecol. Monogr. 45, 161-182.

- Mey, A.W. (1978). The economy of shifting cultivation in Bangladesh. Paper presented to the xth International Congress of Anthropological and Ethnological Sciences, India (Mimeographed).
- Misra, B. (1976). A positive approach to the problem of shifting cultivation in eastern India and a few suggestions to the policy makers. In; *Shifting Cultivation in Forth-East India* (Ed. by B.Pakem, J.B-Bhattacharjee, B-B.Dutta and B.Dutta Hay), pp. 80-91. North East India Counc. Social. Sci. Res., Shillong, Meghalaya.
- Misra, R. (1968). *Ecology Workbook*. Oxford & IBH Publishing Co.
- Misra, R. (1972). A comparative study of net primary productivity of diy deciduous forest and grassland of Varanasi, India. In: *Tropical Ecology* (Ed. by P-M. Golley & P.B. Golley), 279-293. Athens, Georgia.
- Mitchell, E. (1979). *The Analysis of Indian Agro-ecosystems*, Interprint, New Delhi.
- Moore, A-W. & Jaiyebo, E.O. (1963). The influence of cover on nitrate and nitrifiable nitrogen content of the soil in a tropical rain forest environment. *Emp. J. Expt. Agric.* 31, 189-198.

- Mukurjee, R.K. (1975). Some social constraints to agricultural development in north-east India. In: North-eastern Affairs, Annual issue 1975.
- Nakano, K. & Monsi, M. (1968). An experimental approach to some quantitative aspects of grazing by silk worms, Jap. Journ. Ecol. 18, 217-229.
- Newbould, P.J. (1967). Methods for Estimating the primary Production of Forests. International Biological Programme Handbook No. 2. Blackwell Scientific Publications, Oxford.
- Nye, P.H. (1961). Organic matter and nutrient cycles under moist tropical forest. Pt. and Soil 13, 333-346.
- Nye, P.H. & Bertheux, M.H. (1957). The distribution of phosphorus in forest and savannah soils of the Gold Coast and its agricultural significance. J. Agric. Sci. 49, 145-159.
- Nye, P.H. & Greenland, D.J. (1960). The Soil under Shifting Cultivation. Tech. Comm. 51, Comm. Bur. Soils, Harpenden.
- Nye, P.H. & Greenland, J.J. (1964). Changes in the soil after clearing tropical forest. Pt. and Soil 21, 101-112.
- Nye, P.H. & Stephens, D. (1962). 'Soil Fertility', in Agriculture and land Use in Ghana. Oxford Univ. Press.

- Odum, E.P- (1969), The strategy of ecosystem development.  
Science 164, 262-270.
- Odum, E.P. (1971). Fundamentals of Ecology. W.B.Saunders,  
Philadelphia.
- Odum, H.T. (1970). Bain forest structure and mineral  
cycling homeostasis. Ins A Tropical Rain Forest  
(Ed. by H.T. Odum & R.P. Pigeon), pp 3-52.  
USAEG.
- Odum, H.T. & Pigeon, H.P. (1970). A tropical rain forest;  
a study of irradiation and ecology at El Verde,  
Puerto Rico. USAEG, Div. Tech. Inf.
- Oosting, H.J. (1956). The Study of Plant Communities.  
W.H. Freeman, Sanfrancisco, CA.
- Pimentel, D., Hurd, I.E., Bellotti, A.G., Porster, M.J.,  
Oka, I.S.T., Sholes, O.D. & Whitman, R.J. (1973).  
Food production and the energy crisis. Science  
182, 443-449.
- Popenoe, H- (1959). The influence of the shifting  
cultivation cycle on soil properties in Central  
America. Proc. 9th Pacific Sci. Cong, 7, 148-160.

- Raakrishnan, P.S. & Toky, O.P. (1978). Preliminary observations on the impact of Shum (shifting agriculture) on forested ecosystem. *JJ'Resources, Development and the Environment in the Himalayan Region*, pp.343-354. Dept. of Sci. & Tech., Govt. of India.
- Hamakrishnan, P.S., Toky, O.P\*, Misra, B.K. & Saxena, K.G. (1980). Slash and burn agriculture in north-eastern India. *Pire Regimes and Ecosystem Properties* (Ed. by H.Mooney, J.M. Bonnicksen, N.L.Christensen, J.R. Lotan & W.A. Reiners). U-S.D.A. For. Ser. Sen, Tech. Report, Washington, D.G.
- Rambo, A.T. (1978). No free lunch: Fife as an over looked factor in the energetic efficiency of swidden agriculture. In: *Proceeding International Congress of Anthropological and Ethnological Sciences*, N.Delhi, India.
- Rappaport, H.A. (1971). The flow of energy in an agricultural society. *Sci. Am.* 225, 116-122, 127-132.
- Haynal, D.J. & Bazzaz, P.A. (1973). Establishment of early successional plant populations on forest and prairie soil. *Ecology* 54, 1335-43.

''''• ,,,h H.I- U9»^'\* Oliver  
L E. \* Ba.il«'i»\*" vegetation- 01  
tinal ^^

, (.95.). ^-^•^''' taxix. Secondar, » - " ^ -  
\*''' 3t of souther. ^i8«^» ^^,, ,, . «»-88E.  
forest 01 reserve. J- »«\*''••  
m t.e S>>sha forest^ ^ ^^^^^^^ ^^^^^^^^^^ ^ ^ , ,f

B..anov. B.<^ . \* ^^" " ' ; ' . ; " " . «t . in the tropid  
baaboo <.H» (lose.) 49, 384-J6T.  
forests of Bur«^ - B" t

- Raynal, D.J. & Iazzaz (1975). The contrasting life-cycle strategies of three summer annuals found in abandoned fields in Illinois. *J. Ecol.* 63, 587-596.
- Reed, W.E. (1951). Reconnaissance Soil Survey of Liberia. *Agric. Inf. Bull.* 66, U.S. Dept. of Agriculture. Washington.
- Remezov, N.P., Saaoylova, Y.M., Suiridova, I.K. & Bogashova, L.G. (1964). Dynamics of the interaction of oak forest and soil. *Pochrovedenie* 1964(3), 1-14; *Soviet Soil Sci.* 1964, 222-232.
- Rice, E.L. (1974). *Allelopathy*. Acad. Press, New York, N.Y.
- Richards, P.W. (1952). *The Tropical Rain Forest*. Cambridge Univ. Press, Cambridge.
- Rodin, L.E. & Bazilevich, N.I. (1967). *Production and Mineral Cycling in Terrestrial Vegetation*. Oliver and Boyd, Edinburgh.
- Ross, R. (1954). Ecological studies on the tropical rain forest of southern Nigeria III. Secondary succession in the Shasha forest reserve. *J. Ecol.* 42, 259-288.
- Rftzanov, B.G. & Rozanova, I.M. (1964). Biological cycle of bamboo (*Bambusa* Spp.) nutrients in the tropical forests of Burma. *Bot. Zhur. (Moscow)* 49, 384-357.

- Sussell, E.W. (1968). Some agricultural problems of  
*T-Y'*  
 semi-arid areas. <sup>^</sup>'Soil Resources of Tropical Africa  
 (Ed. by R.P. Moss)\* Gamb. Univ. Press.
- Sabu, S.B. (1978). Energy Requirement for some Selected  
 Cultural Practices in a Hilly Region of Meghalaya.  
 M. Tech. Thesis. Dept. of Agric. Energy, I.I-T.,  
 Kharagpur.
- Salisbury, E.J. (1942). *The Reproductive Capacity of*  
 Plants. G. Bell, London.
- Sarukhan, J. (1964). Estudio sucesional de una area  
 talada en Tuitepec Oaxaca. Publ. Esp. Inst. Nac.  
 Invest. Forest. Mexico. 3, 107-172.
- Schlippe, P.D. (1956). *Shifting Cultivation in Africa:*  
 The Zande System of Agriculture. Routledge & Kegan  
 Paul, London.
- Simpson, E.H. (1949). Measurement of diversity. *Nature*  
 163, 688.                    ^^^^
- Singh, J.S. & Misra, R, (1969). Diversity, dominance,  
 stability and net production in the grasslands at  
 Taranasi, India. *Can. J. Bot.* 47, 425-427.
- Staith, W.H., Bormann, P.H. & Likens, ff.E. (1968).  
 Response of chemoautotrophic nitrifiers to forest  
 cutting. *Soil Sei.* 106, 471-473.

- Snedaker, S.C. (1970). Ecological Studies on Tropical Moist Forest Succession in Eastern Lowland Guatemala. Ph.D. Thesis, Univ. of Florida, Gainesville.
- Snedaker, S. & Gamble, J. (1969). Compositional analysis of selected second growth species from lowland Guatemala and Panama. In: Symposium on sea-level canal bioenvironmental studies. I.O.G.S. memorandum BMI-24. Report 9.
- Spedding, C.R.W. & Walshingham, J.M. (1976). The production and use of energy in agriculture. Journ. Agric. Sci. Camb. 77, 19-30.
- Stark, N. (1971a). Nutrient cycling I. Nutrient distribution in some Amazonian soils. Trop. Ecol. 12, 24-50.
- Stark, N. (1971b). Nutrient cycling II. Nutrient distribution in Amazonian vegetation. Trop. Ecol. 12, 177-201.
- Steinhart, J.S. & Steinhart, C.E. (1974). Energy use in the U.S. food system. Science 184, 307-316.
- Tergaa, L.E. (1965). Correlation of nutrient availability in soil and uptake by native vegetation in the humid tropics. M.S. Thesis, Univ. of Florida, Gainesville.

- Tondeur, M.S. (1956). *L'Agriculture nomade - i't. 1 - L'Agriculture Nomade au Congo Beige*, pp.15-108. F.A.O., Rome.
- Valentine, P.S. (1976). A preliminary investigation into the effect of clear cutting and burning on selected soil properties in Pemherton area of western Australia. *Geowest* 8, 43.
- Viro, P.J. (1974). Effects of forest fire on soil. *Fire and Ecosystems* (Ed. by T.T. Kozlowski & C.E. Ahlgren), pp.7-44. Acad. Press, New York.
- Watters, R.P. (1971). *Shifting Cultivation in Latin America*. F.A.O. Forestry Development Paper No. 17, Rome.
- Wells, G.G. (1971). Effects of prescribed burning on physical properties of soil. *A Prescribed Burning Symposium*, pp.80-97. U.S.D.A., For. Ser., south-eastern For. Expt. Stn., Asheville.
- Went, P.W. & Stark, N. (1968). Mycorrhiza. *BioScience* 18, 1035-1039.
- Whittaker, R.H. (1975). *Communities and Ecosystems*. McMillan Publ. Co., Inc., New York.
- Whittaker, R.H., Likens, G.E., Bormann, P.H., Eaton, J.S., & Siccaaa, 3?,G,(1979). The Hubbard Brook ecosystem study's Forest nutrient cycling and element behavior. *Ecology* 60, 203-220.

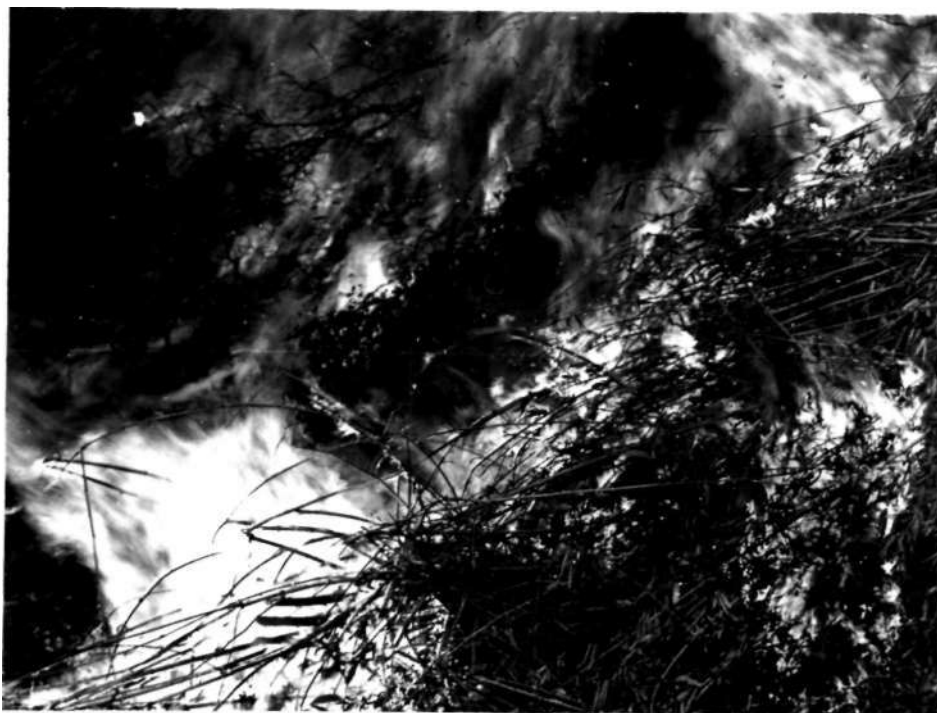
S

C

- Whittaker, R.H. & Woodwell, G.M. (1972). Evolution of natural communities. *Ecosystem Structure and Function* (Ed. by J.A. Wiens), pp.137-156. Oregon State Univ. Press, Corvallis, OR.
- Woodwell, G.M. & Smith, H.H. (ed.) (1969). Diversity and Stability in Ecological Systems. *Brookhaven Symposium in Biol.* 22.
- Woodwell, G.M., Whittaker, R.H. & Houghton, R.A. (1975). Nutrient concentrations in plants in the Brookhaven Oak-pine forest. *Ecology* 56, 318-32.
- Worthington, E.B. (1958). Science in the Development of Africa. G.C.T.A., London.
- Zinke, P.J., Sabhasri, S. & Kunstadter, P. (1970). Soil fertility aspects of the 'Lua' forest fallow system of shifting cultivation. In: *International Seminar on Shifting Cultivation and Economic Development in Northern Thailand*, pp.251-93. Land Development Dept., Bangkok, Thailand.
- Zinke, P.J., Sabhasri, S. & Kunstadter, P. (1978). Soil fertility aspects of the 'Lua' forest fallow system of shifting cultivation. <sup>IVI:</sup> *Farmers in the Forest* (Ed. by P. Kunstadter, E.G. Chapman & S. Sabhasri). East-West Centre, Honolulu, Hawaii.



Plate 1 & 8. Stages in burning of slash during  
jhiim procedures.



**PLATE 1**



**PLATE 2**

Plate 3. Field after burn. Note that burning of large boles and branches is yet to be completed.

Plate 4. Mixed cropping on the slope dominated by maize in the front and rice at the back. Note a clump of banana in the background.



4



# PLATE 3



E*ai*^\*



r\* fw ir  
• : \ ^ r

# PLATE 4

Plate 5. Field after one year of cultivation  
and harvest of crops.

Plate 6. 1 year fallow dominated by Imperata  
cylindrica.



**PLATE 5**



**PLATE 6**

Plate 7. 10 year fallow dominated by bamboo  
(*Dendrocalamus l^aiHton^i*).

Plate 8. 30 year fallow dominated by many  
dicot tree species.



**PLATE ;**



**PLATE" 8**

Maximum temperature ( ^ ),  
Minimum temperature ( O )  
and precipitation ( A ) for the  
year of 1978 at Burnihat.

%i

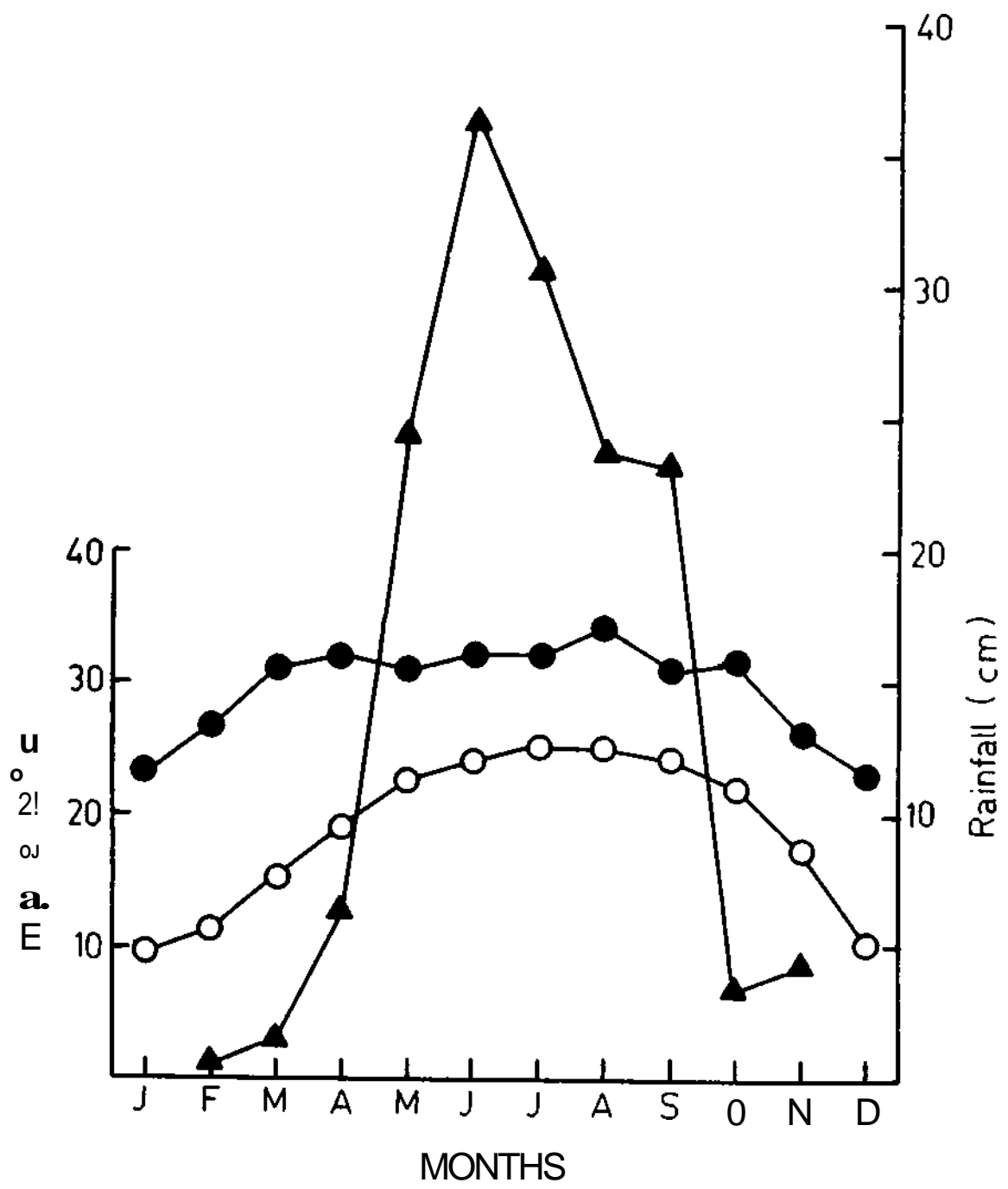


Table I-1

Area under shifting cultivation and the human population dependant upon this practice in north-eastern India (after MukiiHrjee, 1975) .

States/Union 'Perritories	Area under saifting cultivation (ha)	Total population dependent on shifting cultiva- tion (in million)	Percentage of total population dependent on shifting cultiva- tion (1971) to total population of respective 3tates/UT
Arunachal Pradesh	70,300	0.,27	57.69
^fizoram	60,000	0..26	80.74
Meghalaya	76,000	0..35	34.58
:ianipur (Hills)	50,000	0.,30	27.95
rjagaland	83,600	?	?
Tripura	17,000	x/v 0..10	6.42
North Gachar & Mikir Hills of Assam	70,000	4^3 0.,40	0.48

The area under shifting agriculture (Jhum)  
in north-eastern hill regions of India,

92° E

10° E

11

12

13° E

28

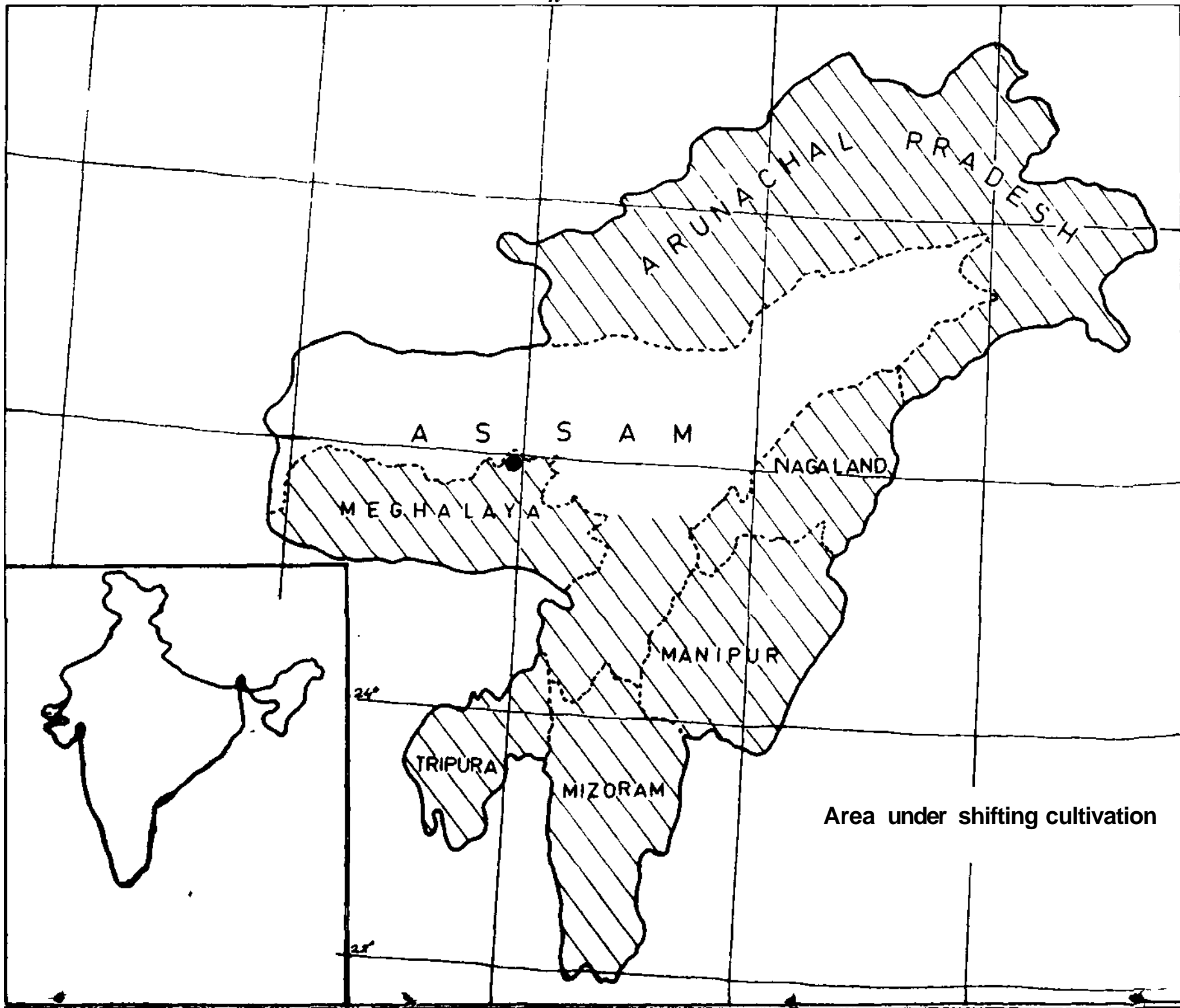
fig

28° N

26°

24°

22°



A S S A M

A R U N A C H A L P R A D E S H

M E G H A L A Y A

N A G A L A N D

M A N I P U R

T R I P U R A

M I Z O R A M

Area under shifting cultivation

PSSiS^^^—^^—II^i-OI)T\_0?\_tHE\_fHE SIS

p^j^l-jRhed paperj including IMse. in press:

- (1) Preliminary observations on the impact of Jhum (shifting agriculture) in forested ecosystem. In: Resources, Development and the Environment in the Himalayan Region. Dept. of Sci. & Tech., Govt. of India, pp.343-354 (1978).
- (2) Slash and burn agriculture in north-eastern India. In: H.Mooney, J.M.Bonni tsen, N.I.Ghristensen, J.E.Lotan and V/A. Reiners (editors), Fire Regimes and Ecosystem Properties. USDA For. Serv. Gen. Tech. Report, Washington, B.C.(1980) (in press). ^
- (3) Forest wealth in the north-eastern India and its conservation. In: Vegetational Wealth of the Himalayas (Special. Volume) (1981)(in press).
- (4) Soil nutrient status of hill agro-ecosystems and recovery pattern after slash and burn agriculture (Jhum) in north-eastern India. Plant and Soil, (1981)(in press).
- (5) Cropping and Yields in agricultural systems of the north-eastern hill region of India. Agro-ecosystems, 8(1981)(in press).

^apgrs ^]^^^t^ £211 pubHaalioaf:

- (6) Studies on energy budget in some agro-ecosystem types of north-eastern hill region of India. J.Appl. Ecol,
- (7) Run-off and infiltration losses related to shifting agriculture (Jhum) in north-eastern India. Environmental Conservation.
- (8) Ecological impact of slash and burn agriculture (Jhum) in north-eastern India, I. Secondary succession, biomass, litter-fall and productivity. J. Appl. Ecol.

- (9) Ecological impact of slash and burn agriculture (Jhum) in north-eastern India. II. Nutrient cycling in successional communities. *J. Appl. Ecol.*

IB STRICT SCIENTIFIERS PRESENTED

- (1) Preliminary observations on ecological impact of shifting agriculture (Jhum) on the forests of N.E.India. In: 8th International Congress of Ecology. Jerusalem, Israel (1978).
- (2) Observation on ecosystem structure and function. In: U.G.C. Seminar on Ecosystems. Andhra Univ., Waltair (1979).
- (3) Agro-ecosystem and forest fallows under slash and burn agriculture at lower elevations of north-east India - an ecological assessment. Focal theme symposium on Environmental Degradation, Agro-forestry and Conservation of Natural Resources. Indian Science Congress (1980).
- (4) Soil nutrient status of hill agro-ecosystems and recovery pattern after slash and burn agriculture (Jhum) in north-eastern India, Symposium on: Development without Destruction. Shillong, Meghalaya (1980).
- (5) Energy efficiencies of traditional versus sedentary agro-ecosystems of the Jhansi hills of Meghalaya. Focal theme symposium on: Impact of the Development of Science and Technology on Environment. Indian Science Congress (1981).
- (6) Directions and rates of change in soil nutrient recovery after varied slash and burn agriculture cycles (Jhum cycles) in north-eastern India. Symposium on: Directions and Rates of Change in Fire-prone Ecosystems. International Botanical Congress, Sydney, Australia (1981).