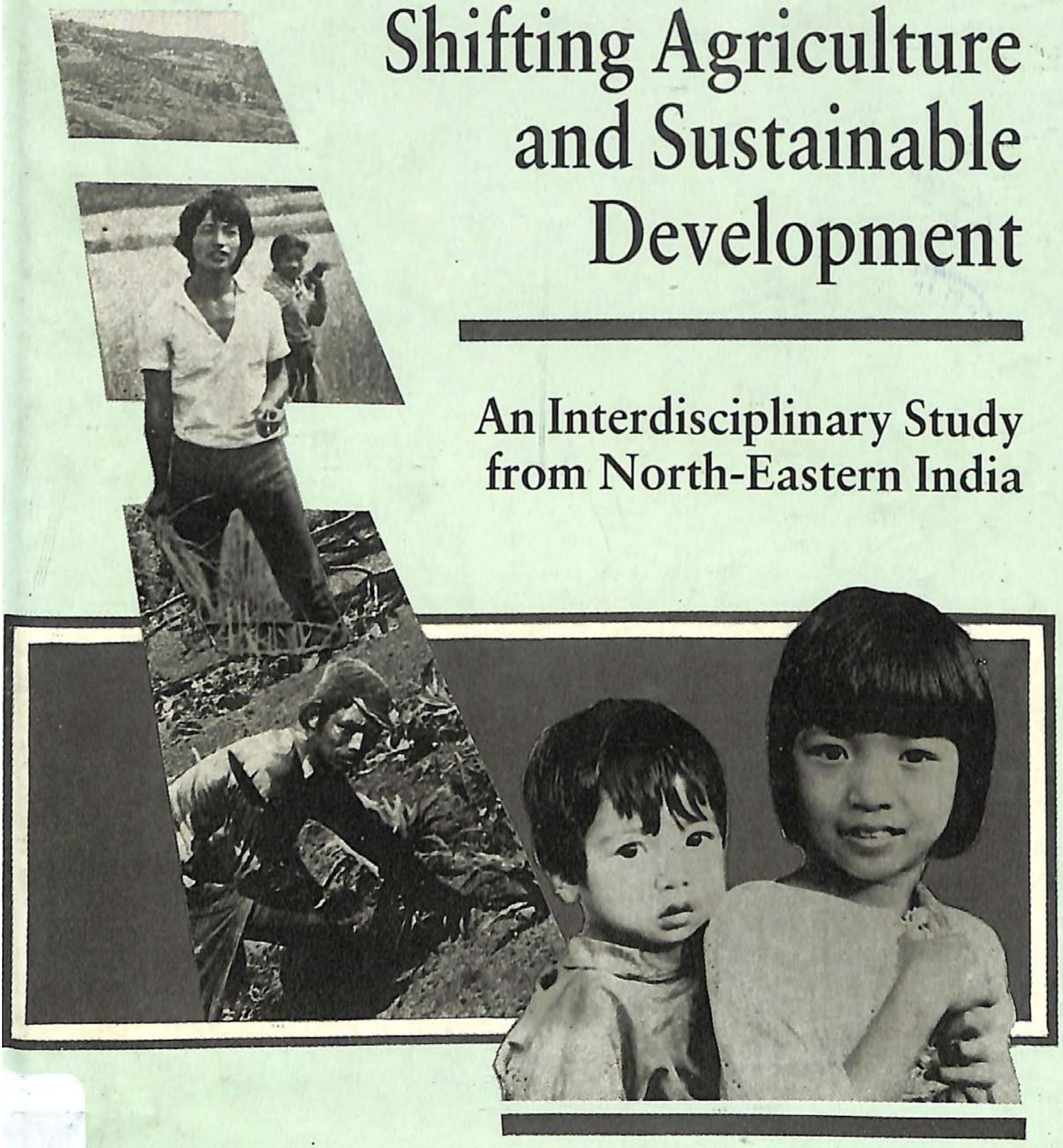
Shifting Agriculture and Sustainable Development

An Interdisciplinary Study from North-Eastern India



P.S. RAMAKRISHNAN

MAN AND THE BIOSPHERE SERIES

MaB

MAN AND THE BIOSPHERE SERIES

Series Editor J.N.R. Jeffers

VOLUME 10

SHIFTING AGRICULTURE AND SUSTAINABLE DEVELOPMENT

An Interdisciplinary Study from North-Eastern India

P. S. Ramakrishnan
School of Environmental Sciences
Jawaharlal Nehru University
New Dehli, 110067, India

PUBLISHED BY
UNESCO
PARIS

AND

OXFORD UNIVERSITY PRESS
DELHI BOMBAY CALCUTTA MADRAS
1993

PREFACE

UNESCO's Man and the Biosphere Programme

Improving scientific understanding of natural and social processes relating to man's interactions with his environment, providing information useful to decision-making on resource use, promoting the conservation of genetic diversity as an integral part of land management, enjoining the efforts of scientists, policy-makers and local people in problem-solving ventures, mobilizing resources for field activities, strengthening of regional co-operative frameworks, these are some of the generic characteristics of UNESCO's Man and Biosphere (MAB) Programme.

The MAB Programme was launched in the early 1970s. It is a nationally based, international programme of research, training, demonstration and information diffusion. The overall aim is to contribute to efforts for providing the scientific basis and trained personnel needed to deal with problems of rational utilization and conservation of resources and resource systems, and problems of human settlements. MAB emphasizes research for solving problems: it thus involves research by interdisciplinary teams on the interactions between ecological and social systems; field training; and applying a systems approach to understanding the relationships between the natural and human components of development and environmental management.

MAB is a decentralized programme with field projects and training activities in all regions of the world. These are carried out by scientists and technicians from universities, academies of sciences, national research laboratories and other research and development institutions, under the auspices of more than a hundred MAB National Committees. Activities are undertaken in co-operation with a range of international governmental and non-governmental organizations.

Man and the Biosphere Book Series

The Man and the Biosphere Series was launched with the aim of communicating some of the results generated by the MAB Programme and is aimed primarily at upper level university students, scientists and resource managers, who are not necessarily specialists in ecology. The books are not normally suitable for undergraduate text books but rather provide additional resource material in the form of case studies based on primary data collection and written by the researchers involved; global and regional syntheses of comparative research conducted in several sites or countries; and state-of-the-art assessments of knowledge or methodological approaches based on scientific meetings, commissioned reports or panels of experts. The Series Editor is John Jeffers, formerly Director of the Institute of Terrestrial Ecology, in the United Kingdom, who has been associated with MAB since its inception.

Shifting Agriculture and Sustainable Development

The overall objective of work within the MAB Programme in the humid tropics is to contribute to the development of sustainable land-use systems that are in tune with the social, cultural and biological characteristics of the peoples and ecological systems of these regions in a time of rapid and far-reaching change. Research activities in these fields are integrally linked with efforts to synthesize and diffuse information on tropical ecology and resource management, and with a programme of training and institutional development.

Field research activities are undertaken by scientists from the tropical countries themselves, sometimes in collaboration with researchers from institutions in temperate regions and with the support of UNESCO, UNEP, FAO and other cooperating international organizations. More than twenty major field projects have been completed or are underway, dealing with such topics as people–forest interactions in East Kalimantan (Indonesia), rehabilitation of degraded forest areas in Guangzhou (China), the effects of increasing human activities on tropical forest ecosystems at Tai (Côte d'Ivoire) and learning from traditional agricultural systems in lowland wetland areas in Mexico. Two projects have generated case studies which have previously been published in the Man and the Biosphere Book Series – on the structure and the function of a nutrient stressed forest system in San Carlos de Rio Negro in Venezuela (Volume 2) and on the social and environmental effects of pulpwood logging in the Gogol Valley in Papua New Guinea (Volume 3).

The present volume presents a wide ranging synthesis of a long-term ecological study of shifting cultivation in north-eastern India, supported by India–MAB, the Department of Environment and Forests, the Department of Science and Technology, the University Grants Commission and other national institutions. The work has been carried out by a team of scientists headed by P.S. Ramakrishnan, Professor at the School of Environmental Sciences at the Jawaharlal Nehru University, New Delhi.

The project in north-eastern India has been wide ranging in scope and content, covering such topics as nutrient cycling, hydrology, plant succession, soil microbiology and socio-economics. The project has sought to combine detailed ecological studies on the dynamics of rural ecosystems with practical suggestions for improving the systems of land use and land management in the region. It has also placed studies on rain forest conservation and management within the broader human ecological context of village function and its redevelopment. Though the present case study is focused on upland areas of north-eastern India, it is hoped that the approaches and concepts set out in this volume will be of wider interest to those interested in the ecological systems and cultures of the humid tropics, as an example of the sort of contribution that scientists can make in assisting tropical peoples to adapt to changing social and economic circumstances.

It is a pleasure for UNESCO to thank Professor Ramakrishnan and his gifted team of Indian scientists for their foresight in undertaking the ambitious research effort in north-eastern India and the leader of the team for his diligence and perseverance in seeing the present volume into print.

MAN AND THE BIOSPHERE SERIES

---

1. The Control of Eutrophication of Lakes and Reservoirs. S.-O. Ryding; W. Rast (eds.), 1989.
2. An Amazonian Rain Forest. The Structure and Function of a Nutrient Stressed Ecosystem and the Impact of Slash-and-Burn Agriculture. C.F. Jordan, 1989.
3. Exploiting the Tropical Rain Forest: An Account of Pulpwood Logging in Papua New Guinea. D. Lamb, 1990.
4. The Ecology and Management of Aquatic-Terrestrial Ecotones. R.J. Naiman; H. Décamps (eds.), 1990.
5. Sustainable Development and Environmental Management of Small Islands. W. Beller; P. d'Ayala; P. Hein (eds.), 1990.
6. Rain Forest Regeneration and Management. A. Gómez-Pompa; T.C. Whitmore; M. Hadley (eds.), 1991.
7. Reproductive Ecology of Tropical Forest Plants. K. Bawa; M. Hadley (eds.), 1990.
8. Biohistory: The Interplay between Human Society and the Biosphere – Past and Present. S. Boyden, 1992.
9. Sustainable Investment and Resource Use: Equity, Environmental Integrity and Economic Efficiency. M.D. Young, 1992.

CONTENTS

SECTION 1
AGROECOSYSTEM AND VILLAGE ECOSYSTEM FUNCTION

SECTION 2
SECONDARY SUCCESSIONAL PATTERNS AND PROCESSES

SECTION 3
MANAGEMENT IMPLICATIONS

FOREWORD

Agriculture is an important economic activity for a large population of the developing world. The view held a few decades ago that over-emphasized industrialization as the main hope of the developing countries has undergone remarkable changes in more recent times. Today, economists emphasize agriculture and rural development as the *sine qua non* of national development. Indeed, such a reorientation wherein rural development is well balanced with industrial growth is now being considered essential to correct serious imbalances in the economy, for the equitable distribution of wealth and for social justice.

It is against this background that increases in agricultural production in the developing world need to be viewed and evaluated. While the 'green revolution' in India, for instance, had positive repercussions in terms of general self-sufficiency in food production, it brought with it the much larger problems of environmental degradations and unequal distribution of wealth. Being largely confined to a relatively small section of the society, its wider inapplicability has led to a renewed scientific interest in traditional systems of agriculture which presumably offer ecological efficiency and sustainability, together with social justice. Sustainable agriculture not only demands efficient use of water and nutrients based on recyling of locally available resources, but also regulated cropping done in a manner that would contribute towards sustaining soil fertility. Application of wrong technology and/or over-exploitation of natural resources may have short-term gains but could often lead to ecological degradation, no longer sustainable by man. Viewed in this context, the north-east Indian case study is significant.

It is well recognized now that conservation and sustainable development are two sides of the same coin, closely interlinked in that one cannot be achieved at the expense of the other. From a human angle, such an integrated approach demands satisfying basic human needs in an equitable manner, maintenance and indeed promotion of social, cultural and biological diversity, and ecological integrity of the system. The north-eastern region of India, with a complex and large natural resource base and a hilly terrain, provides the ecological diversity. The people of the region, comprising many tribes, provide the socio-cultural diversity. To build upon such a diversity profile on a sustainable basis is a challenging opportunity; the traditional knowledge and technology obviously have to be the starting points if peoples' involvement is to be ensured and development sustainable. Whether it be the highly complex jhum (shifting agriculture) systems of the different tribal communities, or the equally fascinating sedentary agricultural systems in the valleys, or the multilayered home gardens, they all link the traditional animal husbandry or domestic sub-systems in the context of the forest ecosystem in which they are set. Any meaningful developmental effort needs to have this traditional knowledge as its basis. While imported technology from outside the region may sometimes be unavoidable in a larger context, its sustainability should be ensured. The burden of proof that such introductions are not detrimental to conservation has to rest on those developmental agencies seeking to introduce the technology. Thus, a holistic approach to conservation and development based on ecological, economic and social considerations has to be worked out. This volume thus raises: (a) issues related to human ecology in the context of village ecosystem function and its redevelopment, (b) bio-ecological issues concerning rain forest conservation, management and redevelopment, and (c) the obvious linkage between the two. Such relationships have therefore been drawn between the natural and social sciences.

The book has three sections : 1, Agroecosystem and village ecosystem function; 2, Secondary successional patterns and processes; and 3, Management implications. While the nine chapters of the first two sections discuss applications of a specific ecological study and its obvious social linkages, the two chapters of the third section consider general issues of conservation and sustainable development of interest to planners, administrators and non-governmental organizations interested in tribal development. This is significant in the Indian context because the geographical distribution of biological diversity and exploitable natural resources often overlap and are to be found in tribal areas. Though the present study is location-specific to north-eastern hill areas of India, the concepts and principles involved would have wider applicability for redeveloping traditional societies elsewhere in the humid tropics.

I wish to acknowledge the substantial contribution on rain forest ecosystem and restoration ecology by the team of about 25 young students who undertook Ph.D. research and an equal number of those who did post-doctoral work with me over the last 18 years. Without their hard work, enthusiasm, devotion, skills and endurance, this study could not have been brought to this level of completion. All of them had to survive extremely difficult field conditions, sometimes even risking their lives to get the work completed. The end-product is a new breed of ecologists who can handle environmental issues with a keen sensitivity to the social sciences.

For their intense academic involvement throughout this study, and help in many ways I especially thank : U. Baruah, T. Bhadauria, R. Boojh, U.M. Chandrashekara, A.K. Das, M. Deb, P. Dev, B.P. Dey, A.K. Gangwar, U. Gupta, V. Jeeva, R.S. Khiewtam, A. Kumar, S.P.S. Kushwaha, R.K. Maikhuri, B.K. Mishra, K.C. Mishra, S. Patnaik, S.C. Ram, K.S. Rao, S.N. Sharma, K.G. Saxena, R.P. Shukla, G.S. Singh, J. Singh, P.S. Swamy, and O.P. Toky.

The financial and/or institutional support received from the Department of Science and Technology, Department of Environment and Forests, Council of Scientific and Industrial Research, University Grants Commission, North-Eastern Hill University, Jawaharlal Nehru University and the G.B. Pant Institute of Himalayan Environment and Development, in India are acknowledged. The Pitamber Pant Environmental Award that I received from the Ministry of Environment and Forests, Goverment of India facilitated this work. The encouragement and support from my friends in UNESCO, Bernd Von Droste, Malcolm Hadley and John Jeffers led to speedy completion of this volume. Efficient typing of the manuscript by Mr Hari Ram facilitated its completion. I acknowledge the support and indulgence of my family (Poonam, Puneet and Sudha, with substantial field support from the first two) and of those personally dear to me, for the time spent away from them.

GENERAL INTRODUCTION

The north-eastern part of India, covering about 0.26 million km^2 of hills, valleys and plateau (Fig.0.1), is ethnically and culturally very distinct from the rest of the country. The region comprises seven states : Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, and is bordered by Bhutan, Tibet, Burma and Bangladesh. Unlike the rest of the country, the people in the area are Tibeto-Mongoloids having migrated into the region from the neighbouring countries and speaking a variety of languages of Mon Khmer and Tibeto-Burman origin. The hills constitute about 70% of the total land area, where shifting agriculture (locally called jhum) is the chief land use. The Brahmaputra valley in Assam is the largest valley land with sedentary wet rice cultivation, and covers an area of about 56 × 10^3 km^2, with a small hill area comprising the Mikir and North-Cachar hills.

LAND

North-eastern India covers 7.76% of the geographical area of the country (Table 0.1). This region has been suggested to have 46.9% of the geographical area under forests, representing about 15.9% of India's forest area (North-Eastern Council, 1984). However, the results obtained by the National Remote Sensing Agency (1983a) suggest a much smaller forest cover for the country as a whole, with a little over 10% good forest cover. Viewed in this context and realizing that much of what is classified as forest in the north-eastern region may be degraded arrested successional stages of forest, these statistical estimates for forest cover of the north-east (National Remote Sensing Agency, 1983b) may need a downward revision.

Of the reported 21,040 km^2 of evergreen rain forest, 8,340 km^2 semi-evergreen rain forest and 102,000 km^2 of moist deciduous forest for India

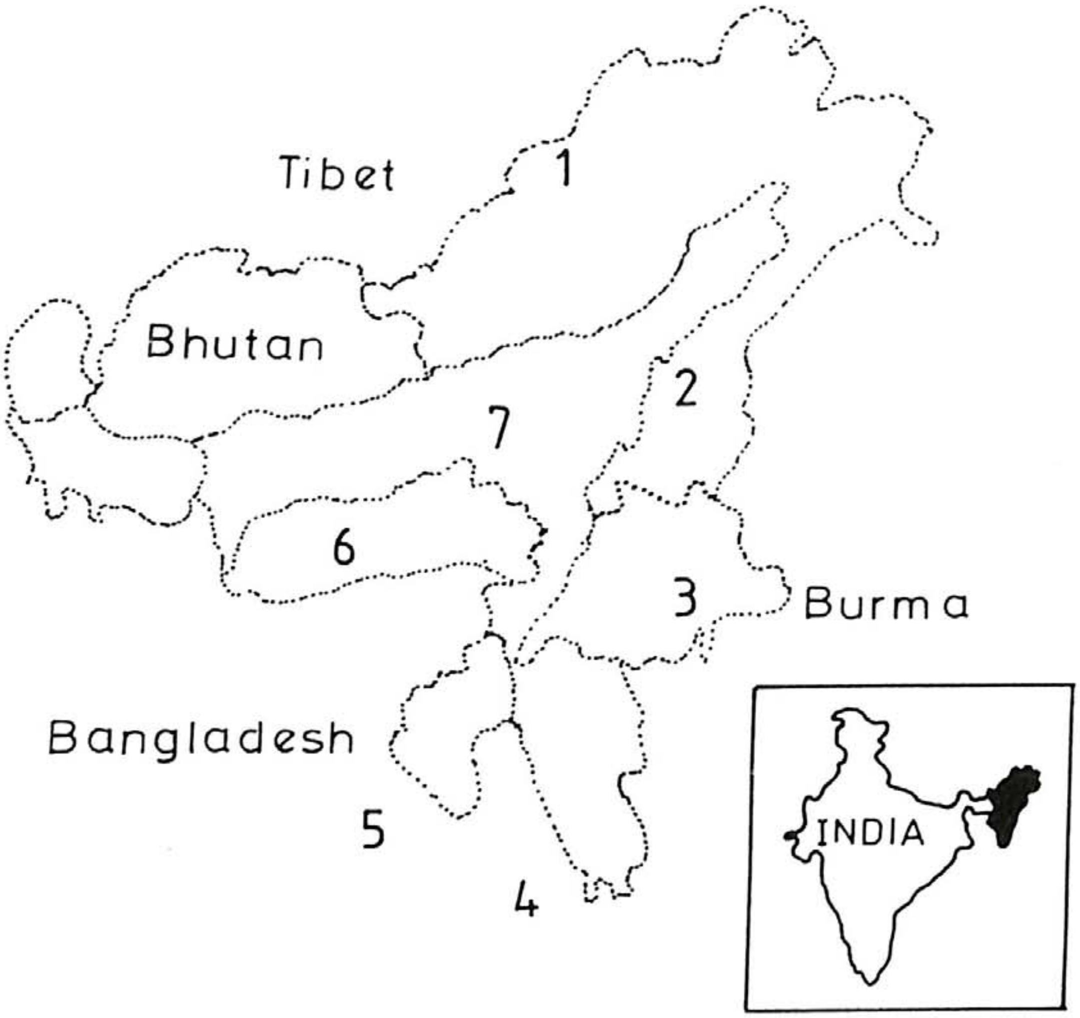


Figure 0.1 The study area of Arunachal Pradesh (1), Nagaland (2), Manipur (3), Mizoram (4), Tripura (5), Meghalaya (6) and Assam (7) in north-eastern India, with an inset map of the country. This is only indicative

Table 0.1 Important land use and population parameters – a comparison of north-eastern region and the nation (from North-Eastern Council, 1984)

Item	*North-east India*	*All India*
Geographical area ($\times 10^3$ ha)	25,505	328,778
Population density (persons km^{-2})	104	201
Decennial growth (%)	35.73	24.43
Area under settled agriculture ($\times 10^3$ ha)	4,090	155,626
Area under forest ($\times 10^3$ ha)	11,956	75,027
Area affected by shifting agriculture ($\times 10^3$ ha yr^{-1})	2,696	NA*

*Not available

(Myers, 1980), a major proportion is confined to north-eastern India, a narrow belt occurs along the western Ghats and some in the Andaman and Nicobar Islands.

VEGETATION

The climax sub-tropical vegetation typically is comprised *Artocarpus chaplasha*, *Michelia champaca*, *Mesua ferrea*, *Alstonia scholaris*, *Morus laevigata*, *Castanopsis indica*, *Ealeocarpus* spp. and *Garcinia* spp. (Puri, 1960; Shukla and Ramakrishnan, 1982b). Secondary successional forests are largely of bamboos dominated by *Dendrocalamus hamiltonii*, *Bambusa tulda*, *Bambusa khasiana* and *Neohouzeua dulloa* (Toky and Ramakrishnan, 1983a; Rao and Ramakrishnan, 1989) or comprised broad-leaved species such as *Alnus nepalensis*, *Vitex peduncularis*, *Vitex glabrata*, *Terminalia belerica*, *Lagerstroemia parviflora*, *Schima wallichii*, *Dillenia pentagyna* and *Cedrela toona*.

The sub-temperate climax forest is a mixed broad-leaved forest with species such as *Quercus dealbata*, *Quercus griffithii*, *Englehardtia spicata*, *Acer laevigatum*, *Betula alnoides*, *Castanopsis hystrix*, *Cinnamomum* spp., *Litsea meissneri*, *Litsea sebifera*, *Machillus kingii* and *Manglietia insignis* as important members (Boojh and Ramakrishnan, 1985; Kheiwtam, 1986). Early successional forests often are either pure pine (*Pinus kesiya*) forests or mixed with *Schima wallichii*, *Schima khasiana*, and *Alnus nepalensis* (Mishra and Ramakrishnan, 1983a; Ramakrishnan and Das, 1983).

Arrested succession of weeds which form extensive formations throughout have exotics such as *Eupatorium* spp., *Mikania micrantha*, and natives such as *Imperata cylindrica*, *Saccharum* spp., *Thysanolaena maxima*, and *Pteridium aquilinum* at different altitudes (Toky and Ramakrishnan, 1983a; Mishra and Ramakrishnan, 1983a).

Forest conversions

Large-scale timber extraction has been carried out in this region during the last few decades (Ramakrishnan, 1985d; Ramakrishnan and Toky, 1983). In fact, a substantial part of the timber needs of the country is met from the north-east. The secondary damage done to the forest due to the falling trees during timber harvest, destroying everything else in their path is also substantial. Bamboo forests, which are seral communities in the region, are being harvested in a major way by the pulping industry.

Much of the fuelwood consumed in the region comes from secondary forests, with about 70% being from the peripheral disturbed zone (Myers, 1980); only a small part comes from the primary forest. However, increased population pressure and rapid depletion of primary forest cover in the region is rapidly changing the situation (Ramakrishnan, 1985d). If about 250 kg of fuelwood is taken as the annual average consumption by an individual, as seen from the study of Sethliew village in Meghalaya (Mishra and Ramakrishnan, 1982), then for a population of 19.58 million (according

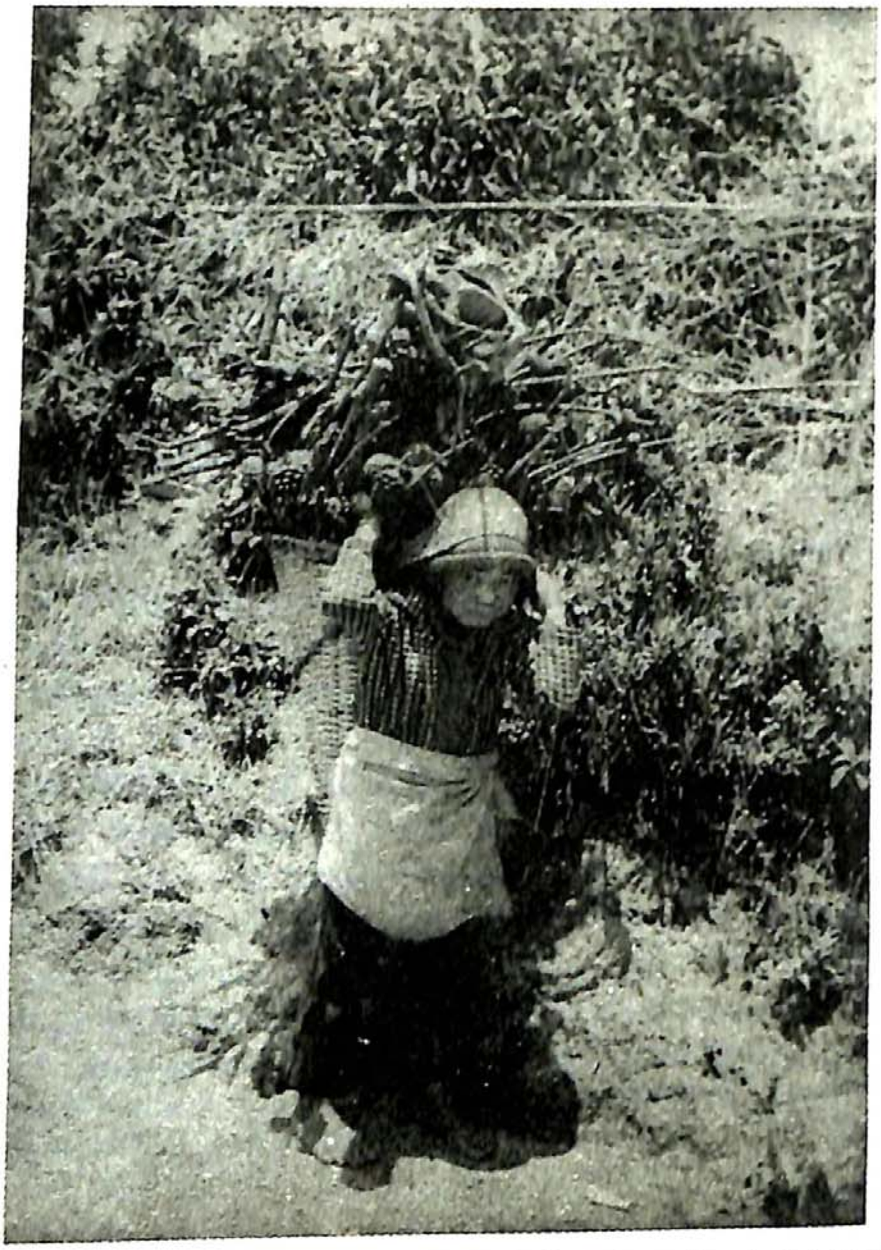


Plate 0.1 Fuelwood in the desertified areas of Meghalaya has often to be carried over long distances

to 1971 census data – Anonymous, 1971) the fuelwood need in the region itself would work out to be 4,895 × 10^6 kg. This is apart from the fuelwood extracted for export outside the region. With rapid increase in population and drastic decline in forest cover, the villagers are now forced to trek 10–15 km outside the village boundary (Plate 0.1).

Forest farming variously termed shifting agriculture, slash-and-burn agriculture, rotational bush fallow agriculture, swidden, and locally called 'jhum' has been an important factor for forest conversion. According to 1971 census data (Anonymous, 1971), 455 × 10^3 families are involved in jhum covering an area of 2,696 × 10^3 ha yr^{-1} in north-eastern India (cf Table 0.1). At a population growth rate of 24–30% per decade, this is expected to go up to 766 × 10^3 families by the turn of the century (North-Eastern Council, 1982). About 2.7 million ha of land are considered to be under jhum in the region. About 7.3 million ha of land were considered to be affected by jhum in 1975. The exact area under jhum, however, is still debatable. This is because the calculations are based upon a number of approximations regarding jhum cycle length and the area owned per family. This does not account for the land area already degraded and rendered unfit for cultivation. Sequential and reliable data on land cover following standardized methodology are required (Singh, 1987); otherwise the conclusions could be misleading. Therefore, these estimates of degraded lands can at best be considered as indicative of the magnitude of the problem, and the values are likely to be underestimates.

CLIMATE AND SOIL

The climate ranges from sub-tropical at lower elevations (Toky and Ramakrishnan, 1981a) to sub-temperate in the hills (Kushwaha *et al.*, 1981a). The temperature/ rainfall pattern shown in Fig. 0.2 for Burnihat at lower elevations in Meghalaya (100 m altitude) and for Shillong at higher elevations in Meghalaya (1,500 m altitude) indicates the typical patterns for the sub-tropical and sub-temperate locations, respectively. The climate is typically monsoonic with an average rainfall of about 2,000 mm, which locally may go up to over 10,000 mm as at Cherrapunji (Ramakrishnan, 1985e). Much of the annual rainfall occurs during the monsoon period from May to September. Winter extends from November to February, with occasional showers. March and April represent the brief dry summer and are accompanied by strong winds. The average maximum and minimum temperatures are 25°C and 12°C, respectively for November to February at Burnihat, and the corresponding temperatures at Shillong are 17°C and 8°C. The rest of the year has on average maximum and minimum temperatures of 32°C and 23°C, respectively, at Burnihat; it was 23°C and 12°, respectively at Shillong. At higher elevations frosts are very common during December–January.

The soils of north-eastern hill areas (Anonymous, 1977) are oxisol (red, mixed red and yellow) or laterosol, (comprising laterite and lateritic types) or ultisol (mountain brown). The Assam valley has inceptisol (alluvial–deltaic). The soils are acidic with average pH ranging from 4 to 5.5. The hill soils are sandy loam derived from metamorphic rocks and are low in phosphorus and potassuim. Nitrogen availability is uncertain partly because of steep slopes of 30–40° angles that are susceptible to intense run-off and leaching losses and partly because of volatilization during slash-and-burn operations related to jhum.

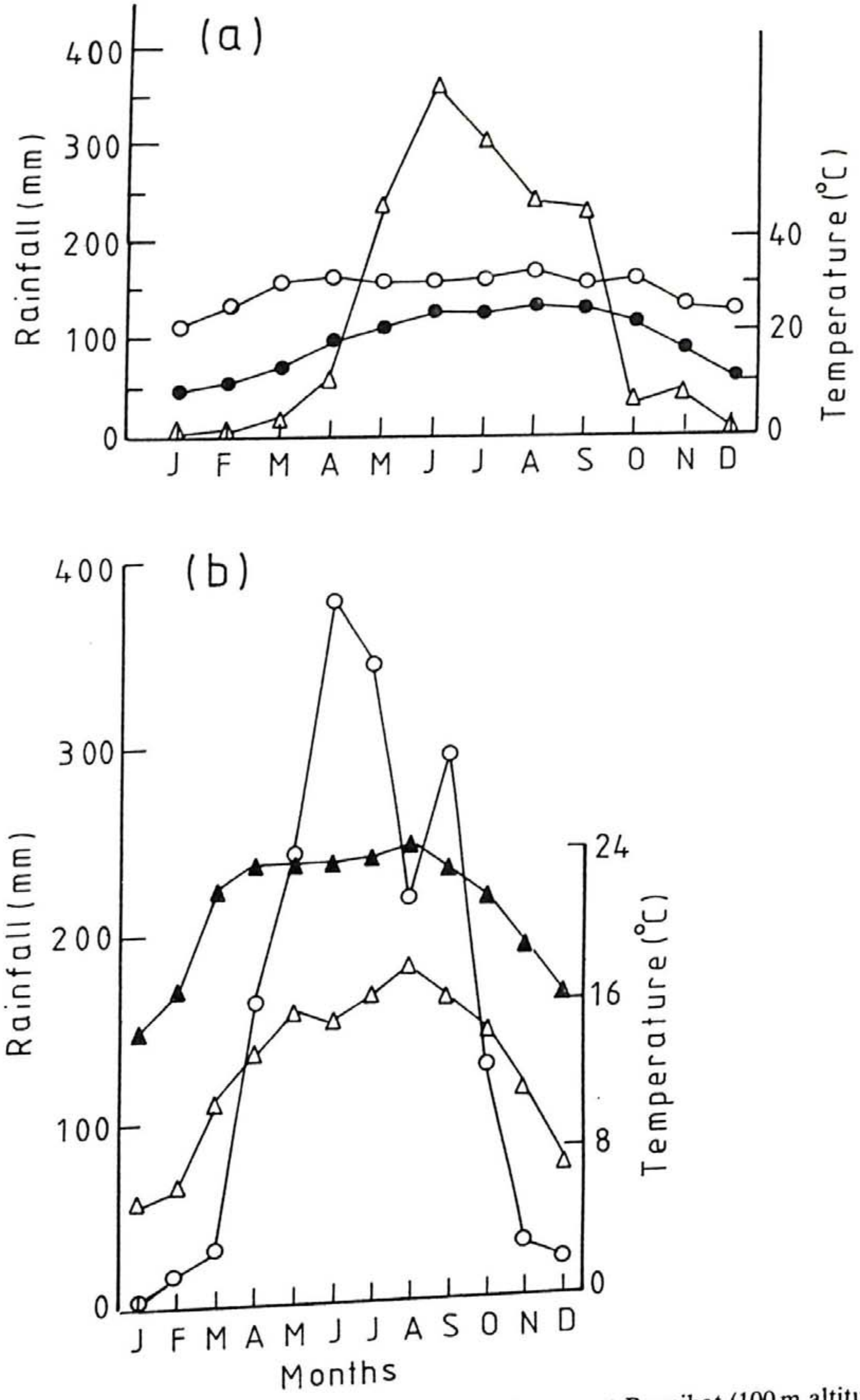


Figure 0.2 Temperature and rainfall data for the study area at Burnihat (100 m altitude) (a), and at Shillong (1,500 m altitude) (b) in Meghalaya, which is typical of the pattern for the north-eastern region, except for local variations (from Toky and Ramakrishnan, 1981a; Kushwaha *et al.*, 1981a). ○, mean max. temperature; ●, mean min. temperature; and △, mean rainfall; (b) ▲, mean max. temperature; △, mean min. temperature; and ○, mean rainfall

Table 0.2 Population structure of the north-eastern region of India (from Anonymous, 1971)

State	*Geographical area* (km^2 × 10^3)	*Population* (× 10^3)	*Tribals* (%)
Arunachal Pradesh	83.5	467.5	79
Assam	78.3	12,911.9	–
Plains	–	12,456.5	11
Hills	–	455.4	58
Manipur	22.4	1,072.8	31
Meghalaya	22.5	1,011.7	80
Mizoram	21.1	321.9	94
Nagaland	16.6	516.5	89
Tripura	10.5	1,556.3	29

PEOPLE

With about 30 million people over a land area of 255 × 10^3 km^2, jhum is practised by the tribals of the six hill states of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura and by the localized hill tribes of Assam. The population structure and land area according to 1971 census data (Anonymous, 1971) given in Table 0.2 suggest that the tribal population largely live in the hill areas.

The population growth in the north-eastern hill region is much above the national average, though the population density is lower (cf Table 0.1). The population grew at a rate much faster in the post-independence period than during earlier times. (Fig. 0.3). The trend in growth in the north-east is similar to the rest of the country, but with a faster rate. Such a trend has had its adverse impact on the natural resources.

There are over 100 different tribes in the north-east, differing linguistically and culturally. Often the tribals change culturally and linguistically over very short distances. Some of the tribes are represented only by a few hundred individuals. The 53 more important tribes in the region with their population size according to 1971 census data (Anonymous, 1971) are shown in Table 0.3.

All the tribes practise jhum. The land is owned by the community. Each village operates in a given demarcated area and the land is distributed amongst the families by the village headman or the village council. The area allocated to a family is determined by the number of members in the family. Once allocated, the land is owned by the family as long as jhum is executed. However, there could be many minor variations depending upon the tribal background (UNESCO, 1983). The residence is mostly fixed and the families operate around the village over a radius of 10–15 km.

The jhum procedures are closely linked with socio-cultural practices and religious beliefs (Ramakrishnan, 1983, 1985c) Thus the Garos believe that

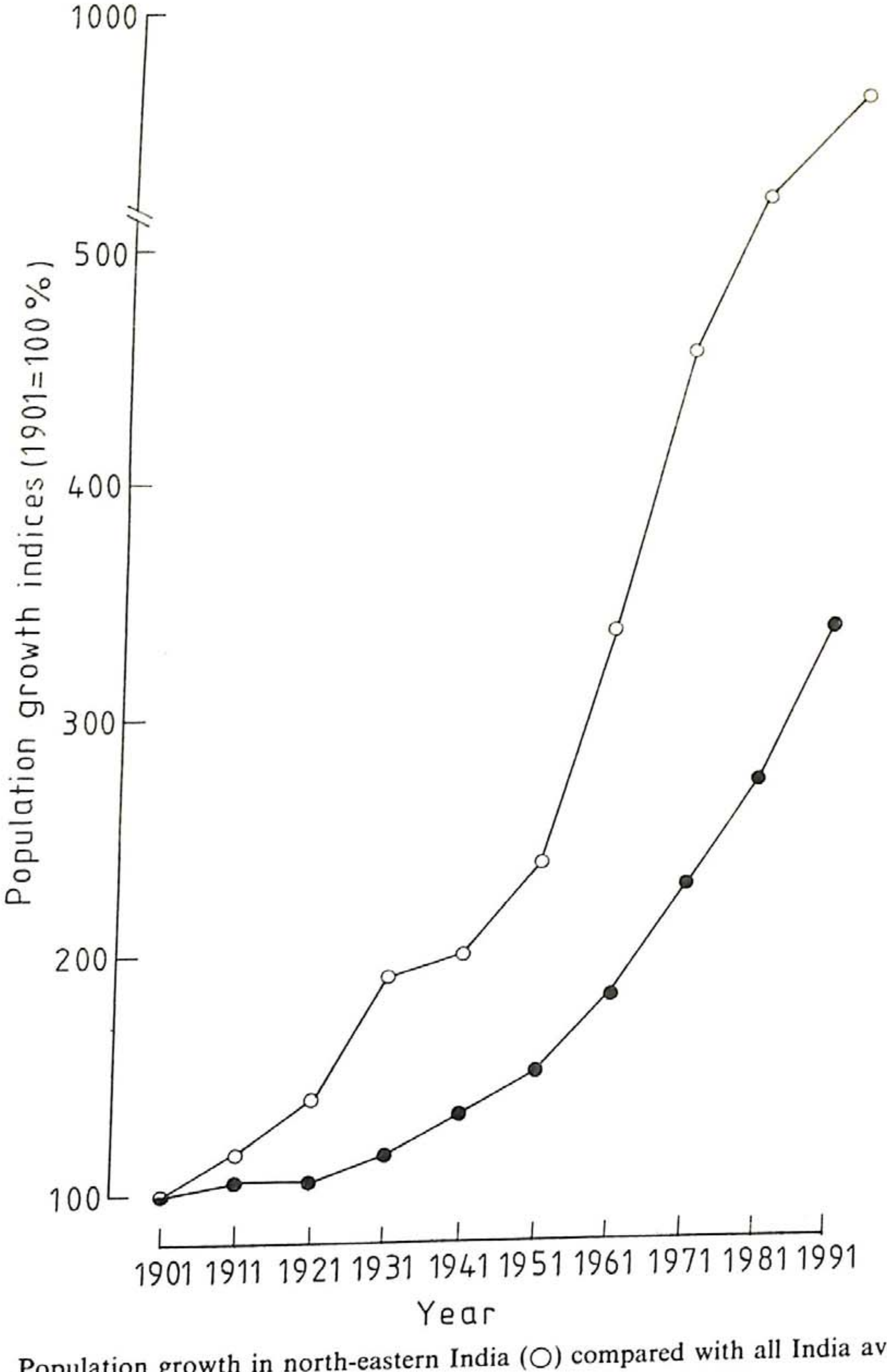


Figure 0.3 Population growth in north-eastern India (○) compared with all India average (●) expressed as growth indices (1901 = 100%)

their deity 'Misipa' helps in obtaining good returns from the jhum plots and therefore jhum operations such as land allocation, felling and burning, and crop harvest are all linked with religious rites and festivities. A detailed account of the cultural profile of many tribes of north-eastern India are given elsewhere (UNESCO, 1983). Indeed, many social anthropologists believe that jhum is a way of life for the tribals and therefore drastic changes

Table 0.3 Some important tribes of north-eastern region of India (from Anonymous, 1971)

Tribe	*Population*	*Tribe*	*Population*
Arunachal Pradesh		**Manipur**	
Adi	99,372	Aimol	108
Aka	2,347	Anal	6,592
Apatani	12,888	Chiru	3,590
Bongro	1,085	Chothe	1,117
Hill Miri	8,174	Hamar	38,207
Khamti	4,078	Kabui	17,360
Miji	3,549	Khoira	406
Mishing	3,359	Maram	19,968
Monpa	28,209	Tangkhul	58,167
Nishi	80,325		
Nocte	23,165	**Mizoram**	
Sherdukpen	1,639	Mizo	270,312
Singpho	1,567	Pawi-Lakher	21,427
Sulung	4,250	Ralte	170
Tagin	20,377	**Tripura**	
Wancho	28,650	Chackma	68,711
		Jamatia	22,446
Meghalaya		Magh	12,378
Garo	411,532	Riang	74,931
Hajong	23,978	Tripuri	268,948
Jaintia	82,493	Mariang	9,710
Khasi	384,006		
Assam		**Nagaland**	
Boro-Kachari	543,615	Angami	43,569
Chutiya	9,103	Ao	62,275
Dimasa	37,900	Chang	15,816
Karbi	17,360	Konyak	72,338
Lalung	10,650	Lhota	36,949
Mech	12,919	Phom	18,017
Mishing	180,684	Rengma	8,578
		Sema	65,227

in agricultural technology are considered to cause social disruptions (Ramakrishnan, 1983; Ramakrishnan and Maikhuri, 1988). However, because of drastically shortened jhum cycles (the length of the intervening fallow phase between two successive croppings on the same site) to 5 years or less, distortions in jhum have occurred. Therefore, there is an obvious need for change.

It is in this context of continuity and the obviously unavoidable need for change that are inherent to all social systems that the various socio-economic activities of the tribal village communities have to be understood, evaluated and linked with forest ecosystem function. In an ecological sense, the emphasis has to be towards linking up natural sciences with social sciences, so that the studies reflect on ecosystem function impacted by human activities and problems related to management of human-impacted ecosystems (UNESCO, 1986). We, therefore, consider here village ecosystem function with emphasis on land use, various physical and biological parameters under which tribal societies operate, and with emphasis on the linked forest ecosystem function. We also consider ecosystem redevelopment strategies on a short- and long-term basis so that social disruptions are minimized, if not avoided.

SECTION 1

Agroecosystem and Village Ecosystem Function

CHAPTER 1

CROPPING AND YIELD PATTERNS AND ENERGY BUDGET UNDER JHUM

INTRODUCTION

Agriculture is the predominant activity of a large majority of the world population. Industrialization of agriculture through large fossil fuel energy subsidies, sophisticated chemical control measures for pests and diseases, and high yielding crop varieties has resulted in huge increases in agricultural yields during the last half century. Such agricultural systems are efficient in terms of human time and labour but suffer from many deficiencies. They are highly inefficient from an overall energetic point of view, because five to ten units of fuel energy are required to produce a single unit of food energy (Steinhart and Steinhart, 1974). Apart from the ecological instability of the monoculture of a single high-yielding variety of crop, modern agriculture also causes varied environmental problems related to intensive use of chemical fertilizers and pesticides. The obvious inapplicability of such systems as models for development in an energy limited world has led to a renewed interest in an understanding of traditional agricultural systems, which presumably offer higher ecological efficiency.

The forest farmer in the humid tropics has managed his traditional 'shifting agriculture', variously termed as 'slash-and-burn agriculture', 'rotational bush fallow agriculture' or popularly known in India as 'Jhum', for centuries, with optimum yield on a long-term basis, rather than trying to maximize production on a short-term basis (Watters, 1960; Spencer, 1966; Ruthenberg, 1971; Soemarwoto, 1975; Gliessman *et al.*, 1981; Ramakrishnan, 1984a).

Shifting agriculture systems have been held up as models of productive efficiencies where 5–50 units of food energy are obtained for each unit of energy expended (Rappaport, 1971; Steinhart and Steinhart, 1974). The possibility for increased crop production has been suggested (Greenland, 1975; Revelle, 1976; Mutsaers *et al.*, 1981) without departing too much from these traditional systems that have been considered as the most evolved system for the forested areas of the tropics and the sub-tropics (Conklin, 1957; Carneiro, 1960; Nye and Greenland, 1960; Watters, 1971; Ramakrishnan, 1985a, 1985c, 1988c).

Earlier attempts at an evaluation of the cropping patterns, monetary and energy efficiencies of shifting agriculture elswhere (Ruthenberg, 1971; Watters, 1971) have been on isolated systems, often without fully defining the parameters under which a given system operates and without making adequate comparisons between all available agroecosystem types. Our studies on the jhum systems of north-eastern India have made such comparisons possible, with greater precision. We have been able to look at jhum systems under varied jhum cycles (the length of the intervening fallow period between two successive croppings at the same site) (Toky and Ramakrishnan 1981a; Mishra and Ramakrishnan, 1981; Maikhuri and Ramakrishnan, 1990a,b), under diverse ecological conditions (Ramakrishnan, 1988d, 1990) and under different socio-economic and cultural backgrounds of societies (Ramakrishnan, 1983; Patnaik and Ramakrishnan, 1989; Kumar and Ramakrishnan, 1989a; Maikhuri and Ramakrishnan 1990a,b).

JHUM AGROECOSYSTEM IN NORTH-EASTERN INDIA

Realizing that there are over a hundred different tribal communities which are highly insulated because of language, topography and socio-cultural factors, one could reasonably expect over a hundred different variations in this land use practice. If ecological conditions are superimposed on this then the heterogeneity gets very complex indeed. Therefore, it is important to realize that we are talking of a variety of jhum systems rather than a single, homogeneous system of 'shifting agriculture', as often assumed in the scientific literature.

Jhum is the chief land use practice in the north-eastern hill region of India. The jhum cycle, until recently, was more than 20 years (Ramakrishnan and Toky, 1978; Ramakrishnan *et al.*, 1981a,b) but has now come down to an average of 4–5 years. Long cycles were possible earlier because population pressure was not heavy and land availability did not limit the cycle. In north-eastern India, the average size of a jhum plot varies from 1.0 to 2.5 ha. The average family consists of two adults and three to four children.

Jhum at lower elevations

The low elevation jhum prevalent at Burnihat in Meghalaya (Plate 1.1) is typical of the version found throughout the north-eastern hill areas in that: (1) the cultivation is carried out on slopes of 30–40° angle, (2) the climate

Plate 1.1 A general view of the jhum plot at Burnihat (90 m) in Meghalaya on a steep slope of 30–40° angle. In the foreground is wet rice cultivation in the valley land which is common in the region

is monsoonic with a high rainfall of over 2,200 mm followed by a dry winter and a brief warm summer, supporting a mixed sub-tropical humid forest, (3) the normal jhum cycle is of 4–5 years, but rarely longer, and more importantly the forest is clear-felled before cropping (Toky and Ramakrishnan, 1981a).

The study site at Burnihat in (100 m altitude) the Khasi hills of Meghalaya and about 90 km north of Shillong is located 26°N and 91.5°E. The soil is red, sandy loam and of lateritic origin (oxysol) with a pH ranging from 5 to 7. The climate is monsoonic with an annual average rainfall of 2,200 mm, 90% of which occurs between May to September (Toky and Ramakrishnan, 1981a). The summer temperatures have an average maximum of 33°C and a minimum of 29°C the average maximum winter temperature is 25°C and the minimum is 15°C.

During the winter months (December–January), the undergrowth is slashed, and small trees and bamboos are felled. Short tree stumps and large tree boles are left intact. The underground organs of different species are not disturbed. This laborious process is often completed by the men from two or three families. Such a joint effort is one of the essential ingredients of a well-knit social organization. This effort, along with the process of allotment of sites for jhum by the village headman who is in

Plate 1.2 A jhum plot at Lailad (296 m) in Meghalaya after the slash-and-burn operation. Uncut trees and tree stumps are left *in situ*. A small hut (top left) is for the farmer to live in and protect his field. Note the small heaps of ash left after a second burning of the unburnt biomass

overall control of the village community, helps to promote kinship among the members of the village, and among many communities such as the Garos and the Mikirs (Maikhuri and Ramakrishnan, 1990a).

Towards the end of March or the beginning of April, before onset of the monsoon, the debris is burnt *in situ*. Before burning, a fire line is cleared around the field. Burning is often repeated to destroy any unburnt material that has first been collected in heaps. A bamboo hut is built for temporary living. The family's presence protects the field from wild animals (Plate 1.2).

Sowing is done after the first few monsoon showers. The seed mixtures used for different jhum cycles may vary considerably. Whereas cereals are emphasized under long jhum cycles, perennials and tuber crops are emphasized under short jhum cycles, as by the Garos in Meghalaya (Toky and Ramakrishnan, 1981a), or by the Nishis in Arunachal Pradesh (Maikhuri and Ramakrishnan, 1990b). The details of the crops sown at Burnihat are given in Table 1.1. Some 8–35 crop species are grown together at Burnihat, but the number may be up to 35 species elsewhere in Arunachal Pradesh (Maikhuri and Ramakrishnan, 1990b) or in the Garo and the Naga hills (Kushwaha and Ramakrishnan, 1987). Seeds of pulses, cucurbits, vegetables and cereals are mixed with dry soil from the site to ensure their

Table 1.1 Phytosociology of crops under different jhum cycles of the Garos at Burnihat in Meghalaya (from Toky and Ramakrishnan, 1981a)

	Frequency (%)			*Density* (plants mm^{-2})			*Basal area* (cm^2)			*IVI**		
Crops species	*30-yr*	*10-yr*	*5-yr*	*30-yr*	*10-yr*	*5-yr*	*30-yr*	*10-yr*	*5-yr*	*30-yr*	*10-yr*	*5-yr*
Grain and seed												
Oryza sativa	100	100	100	8.6	12.2	1.5	52.9	23.9	3.2	163.6	175.5	114.2
Sesamum indicum	80	35	5	1.1	0.5	0.1	1.5	1.4	0.1	28.3	19.9	4.6
Zea mays	80	25	15	1.8	1.5	0.2	4.8	1.8	0.2	38.2	23.4	13.2
Setaria italica	90	30	15	2.1	0.5	0.2	0.9	0.2	0.1	36.9	14.9	14.8
Phaseolus mungo	5	–	–	0.1	–	–	0.01	–	–	1.9	–	–
Ricinus communis	20	–	–	0.2	–	–	1.9	–	–	9.0	–	–
Leaf and fruit vegetables												
Hibiscus sabdariffa	10	20	20	0.1	0.2	0.2	0.5	0.8	0.8	3.8	10.7	19.7
Hibiscus esculentus	–	10	–	–	0.1	–	–	0.1	–	–	4.8	–
Capsicum frutesence	–	5	–	–	0.1	–	–	0.02	–	–	2.2	–
Lagenaria leucantha	10	5	–	0.2	0.3	–	0.2	0.2	–	3.7	3.6	–
Cucurbita maxima	5	–	–	0.1	–	–	0.1	–	–	1.6	–	–
Cucumis sativa	10	–	–	0.2	–	–	0.2	–	–	3.7	–	–
Momordica charantia	–	10	–	–	0.2	–	–	0.01	–	–	4.7	–
Musa sapientum	–	10	30	–	0.1	0.3	6.8	–	20.3	–	21.6	95.4
Tuber and rhizome												
Manihot esculenta	5	10	10	0.1	0.1	0.1	0.2	0.7	0.7	1.8	6.3	11.0
Colocasia antiquorum	5	5	15	0.2	0.2	0.2	2.0	3.6	3.6	5.2	12.3	27.0
Zingiber officinalis	5	–	–	0.2	–	–	0.1	–	–	1.7	–	–

* IVI = importance value indices

Plate 1.3 A Garo farmer at Lailad (296 m) in Meghalaya dibbling the seeds of rice along the bottom of the slope using a bamboo stick

uniform distribution, and broadcast soon after the burn. Maize seeds are dibbled at regular intervals amongst other crops. Similarly, rice is sown into the crop mixture by dibbling with a long stick, after the first rainfall in mid-April (Plate 1.3). Semi-perennial and perennial crops such as ginger, colocasia, tapioca, banana and castor are sown intermittently throughout the growing season (Plate 1.4). The leaves of *Ricinus communis* are used for rearing young silk worm caterpillars. Crops are harvested as they mature (Table 1.2) making room for the other crops left behind. Other crop species could be *Coix lacryma – jobi*, *Eleusine coracana*, *Ipomoea batatus*, *Dioscorea alata*, etc. (Maikhuri and Ramakrishnan, 1990b).

Throughout the cropping period, weeds pose a problem. The most common weeds are root sprouts, rhizome sprouts, stump sprouts, tree seedlings, grasses and herbs. Under long jhum cycles, the problem is less severe than under short jhum cycles (Saxena and Ramakrishnan, 1984a), where many weeds, particularly *Imperata cylindrica*, keep sprouting from underground rhizomes and are difficult to eradicate. Others, like *Eupatorium odoratum* are kept under control through frequent slashing. Hand-hoeing is usually done twice (3–4 times under shorter cycles) during the cropping, mainly by women.

Table 1.2 Sequential harvesting of crops on jhum plots under a 30-year cycle of the Garos at Burnihat in Meghalaya (from Ramakrishnan *et al.*, 1981a)

Species	*Harvesting time*
Setaria italica	Mid-July
Zea mays	Mid-July
Oryza sativa	Early September
Lagenaria spp.	"
Cucumis sativa	"
Zingiber officianalis	Early October
Sesamum indicum	"
Phaseolus mungo	"
Cucurbita spp.	Early November
Manihot esculenta	"
Colocasia antiquorum	"
Hibiscus sabdariffa	Early December
Ricinus communis	(Perennial crop)

All the seeds were sown in April

Jhum at higher elevations

The jhum done by the Khasis at higher elevations (1,500 m altitude and above) in Meghalaya is a modified version of the typical one outlined above. It is commonly practised around Shillong (Mishra and Ramakrishnan, 1981). The study sites at villages (25.34°N and 91.56°E) around Shillong in the Khasi hills of Meghalaya are at an altitude of about 1,500 m. The soil is acidic with pH ranging from 4 to 6. The climate is monsoonic with about 80% of the annual rainfall of 3,070 mm occurring during May – September (Gangwar and Ramakrishnan, 1987a). The average maximum and minimum temperatures during this season are 23°C and 13°C, respectively. The winter is from November to February with average maximum and minimum temperature of 18°C and 7°C, respectively, and with occasional showers. Frosts occur during December–January. The mild dry summer during March–April has an average maximum and minimum temperature of 22°C and 11°C, respectively.

The vegetation consists of sparsely distributed pine trees (*Pinus kesiya*) with much undergrowth of shrubs and herbs. The pine trees are not felled, but the lower branches are slashed in December. The slash is arranged in parallel rows running down the slope and then allowed to dry (Plate 1.5). In the month of March, soil is placed on top of the slash, so as to form ridges alternating with furrows of compacted soil running down the slope. Consequently the burn of the slash is slow and controlled. A fire line of cleared vegetation around the plot helps to check its spread.

The crop mixtures differ from that of the low elevation jhum in that tuber crops such as *Solanum tuberosum*, *Ipomoea batatus* and *Colocacia antiquorum* are planted on the ridges (Mishra and Ramakrishnan, 1981).

Plate 1.4 A jhum plot at Lailad (296 m) in Meghalaya under mixed cropping. *Zea mays* and *Colocasia antiquorum* are clearly visible. In this plot under a 10-year jhum cycle 10–13 crop species are grown together

These are planted soon after the burn and before the onset of the monsoon. Sowing of *Zea mays*, *Phaseolus vulgaris* and a few cucurbits are done just after the onset of the monsoon. Along each ridge, potato and *Zea mays* are sown together in three distinct rows. *Colocasia antiquorum* is generally confined to the top and bottom part of each ridge and the cucurbits are sown at random. *Phaseolus vulgaris* is sown around pine trees for their support.

After the harvest of the tuber crops in July and August, (Plate 1.6) a winter crop of potato is often sown along the ridges. Harvesting of *Zea mays* and the legume *Phaseolus vulgaris* is done in September and October, after which *Brassica oleracea* seedlings are planted along with the winter crop of *Solanum tuberosum*. The second potato crop is harvested during November, and then the field is left uncultivated between December and March. If a second year of cultivation is done, the same procedures are followed; otherwise, the land is fallowed for natural regrowth of vegetation.

The mixture of crops used would vary depending upon the jhum cycle (see Table 1.10). Under a long jhum cycle of 15 years, cropping is done for 1 year only, and no fertilizer is used. Under a 10-year cycle, organic manure in the form of pig dung and vegetable manure is applied at the rate of

Plate 1.5 A Khasi lady is laying down small branches and twigs of trees and undergrowth for drying. In this modified version of jhum at Shillong (1,500 m) in Meghalaya, the dried slash is subsequently topped over by a thin soil layer and subjected to controlled burning. These ridges would alternate with compacted furrows; the crops are sown on the ridges

600 kg $ha^{-1}yr^{-1}$ (oven dry weight). Under a 5-year jhum cycle, cropping is carried out for 2–3 years continuously after slash-and-burn, but the crops grown are only *Solanum tuberosum*, *Zea mays*, and *Brassica oleracea*. Variations in crop mixtures do occur (Gangwar and Ramakrishnan, 1987a); occasionally a monocrop of potato may be raised under shorter cycles. During cropping, both organic (pig dung and vegetable manure) and inorganic (nitrogen : phosphorus : potassium in the ratio of 1:1:1) fertilizers are applied at the rate of 1,000 kg ha^{-1} and 10 kg ha^{-1}, respectively, for the first and second cropping in the 1st year of cultivation, and 1,850 kg ha^{-1} and 20 kg ha^{-1}, respectively for the first and second cropping, in the 2nd year.

Herbaceous weeds grow from seeds, rhizomes or root sprouts. *Eupatorium adenophorum*, a noxious weed, may arise through seeds or root sprouts. *Imperata cylidrica* comes up chiefly through fire resistant underground rhizomes and is common in the low elevation jhum too. *Pteridium aquilinum* and *Dicranopteris linearis* are other important weeds that, along with root or stem sprouts of trees and tree seedlings, are kept under control through frequent slashing. Hand-hoeing along the ridges may be done 2–3 times during the season.

ECONOMIC YIELD PATTERN UNDER JHUM

A view point commonly expressed, more often not based on precise data, is that jhum as an agricultural system is unviable on economic considerations compared to settled farming like terracing of the hill slopes. Where data are given, these studies do not define the parameters under which the observations were made. In any study of this nature, one ought to specify the jhum cycle, the crop mixtures, the comparability of plots in terms of ecological factors, the various inputs that go into the system as manure and labour, and the conversion factors used while expressing mixed crop yield as yield of rice or as monetary return. This confusion regarding crop yield also exists for agroecosystems in north-eastern India. In fact, the rice yield under jhum was shown to be as low as 190 kg ha^{-1} (Borthakur *et al.*, 1978) to a high value of 1,200 kg ha^{-1} (Misra, 1976). The Agro-Economic Research Centre, Jorhat, Assam conducted surveys on jhum rice yield and concluded that the average yield of 800–900 kg ha^{-1} in the Garo hills, Mizoram and Arunachal Pradesh is comparable to the average yield of 1,145 kg ha^{-1} for the country as a whole for 1971–1972. A study of rice yields at Burnihat in the lower elevation of Meghalaya (Sahu, 1978) gave yearly outputs of 853 kg ha^{-1} compared to 3,428 kg ha^{-1} under valley cultivation and 738 kg ha^{-1} under terrace cultivation. A report by the Indian Council of Agricultural Research (Borthakur *et al.*, 1978) related rice yield under terracing (1,860 kg ha^{-1}) compared to a very low 190 kg ha^{-1} under jhum.

Unfortunately, none of these studies specify the fertilizer input under different land uses nor do they indicate the jhum pattern, the cycle of which determines the yield. None of the studies also specify whether yields from other crops are included in the final figures and how the conversions to rice yield was arrived at for the mixed cropping jhum system. We shall evaluate some of these aspects in the following pages considering actual yield, and using money and energy as other currencies for evaluation. We shall also consider the ecological implications of the results obtained for better management of the jhum system.

Yield pattern under jhum (typical version) of varied cycles at lower elevations

In a comparative analysis of jhum done by the Garos, under 30-, 10- and 5-year cycles, differences were observed, between them at Burnihat, at lower elevations in Meghalaya (Toky and Ramakrishnan, 1981a). Under the long jhum cycle of 30 years, cereals constitute the major component of the crop mixture. However, under a 5-year cycle the emphasis shifts to seasamum,

Table 1.3 Biomass of crops under different jhum cycles of the Garos at Burnihat in Meghalaya (from Toky and Ramakrishnan, 1981a)

	Biomass (kg ha^{-1} yr^{-1})					
	30-yr		*10-yr*		*5-yr*	
Crop species	*Root*	*Shoot*	*Root*	*Shoot*	*Root*	*Shoot*
Seed grain						
Oryza sativa	1,213	7,614	268	2,440	53	381
Sesamum indicum	163	1,519	103	1,637	8	150
Zea mays	243	3,342	113	1,623	9	136
Setaria italica	69	716	13	121	5	41
Phaseolus mungo	1	38	–	–	–	–
Ricinus communis	131	996	–	–	–	–
	(1,820)	(14,225)	(497)	(5,821)	(75)	(708)
Leaf and fruit vegetables						
Hibiscus sabdariffa	23	301	72	1,177	90	1,232
Hibiscus esculentus	–	–	8	89	–	–
Capsicum frutesence	–	–	2	4	–	–
Lagenaria leucantha	3	189	2	131	–	–
Cucurbita maxima	3	88	–	–	–	–
Cucumis sativa	1	49	–	–	–	–
Momordica charantia	–	–	2	17	–	–
Musa sapientum	–	–	825	3,350	3,325	11,475
	(30)	(627)	(911)	(4,768)	(3,415)	(12707)
Tuber and rhizome						
Manihot esculenta	339	313	1352	960	690	620
Colocasia antiquorum	334	43	373	27	221	25
Zingiber officinalis	10	4	–	–	–	–
	(683)	(360)	(1,725)	(987)	(911)	(645)

Values in parentheses are totals of each category

leafy vegetables and tuber crops, although rice is an important crop (Table 1.1).

Such a shift in pattern due to shortening of the cycle is fairly common in the region as was also shown for the Nishis of Arunachal Pradesh (Maikhuri and Ramakrishnan, 1990b), and this is significant. Under short cycles where the soil is relatively infertile compared to that under longer cycles, the farmer shifts his crop species towards those which have a better nutrient-use efficiency. Such a shift, with emphasis on perennial crops also gives better protective cover to the soil, checking water-related erosive losses more effectively, once the cover is established (Toky and Ramakrishnan, 1981b).

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 cycles, respectively (Table 1.3). 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 30-year cycles,

Table 1.4 Comparison of mean economic yield of crops under different jhum cycles of the Garos at Burnihat in Meghalaya (Values in parentheses are totals of each category, – indicates absence) (from Toky and Ramakrishnan, 1981a)

	Total yield (kg ha^{-1} yr^{-1})			*Moisture content* %
	30-yr	*10-yr*	*5-yr*	
Grain and seed				
Oryza sativa	1,161	378	66	20
Sesamum indicum	446	541	25	7
Zea mays	770	397	30	15
Setaria italica	193	23	9	17
Phaseolus mungo	10	–	–	25
Ricinus communis	5	–	–	12
	(2,585)	(1,339)	(130)	
Leaf and fruit vegetables				
Hibiscus sabdariffa	44	139	96	75
Hibiscus esculentus	–	50	–	65
Capsicum frutesence	–	1	–	80
Lagenaria leucantha	140	81	–	93
Cucurbita maxima	62	–	–	91
Cucumis sativa	16	–	–	92
Momordica charantia	–	5	–	82
Musa sapientum	–	105	488	78
	(262)	(381)	(584)	
Tuber and rhizome				
Manihot esculenta	339	1,352	690	59
Colocasia antiquorum	260	294	180	79
Zingiber officinalis	10	–	–	52
	(609)	(1,646)	(870)	
Silk worm				
Cocoon (silk)	4	–	–	2
Pupae (without cocoon)	0.2	–	–	90

respectively. The biomass obtained from tuberous and rhizomatous crops under a 10-year cycle was almost twice the output of the other two cycles.

Maximum economic yield per hectare for rice, maize and *Setaria italica* was obtained under a 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 (Table 1.4). However, the total economic yield of leafy and fruit vegetables, and tuberous and rhizomatous crops was higher under 5-and 10-year jhum cycles than under a 30-year cycle. The high yields of seasamum, tapioca, banana and leafy vegetables under a short jhum 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 (Toky and Ramakrishnan, 1981a).

Table 1.5 Monetary input–output (Rupees $ha^{-1} yr^{-1}$) under different jhum cycles at Burnihat in Meghalaya (from Toky and Ramakrishnan, 1981a)

	Jhum		
	30-yr	*10-yr*	*5-yr*
Input	2,616	1,830	896
Output	5,586	3,354	1,690
Net gain/loss	2,970	1,524	794
Output/input	2.13	1.83	1.88

Table 1.5 compares the monetary output/input analysis of the jhum under different cycles. The reduction in overall economic return is very obvious, when cost is calculated on the basis of prevailing market rates. The decrease in economic return under short jhum cycles is related to reduced soil fertility (Ramakrishnan and Toky, 1981) and increased weed potential of the site (Saxena and Ramakrishnan, 1984b). Similar results are shown through studies done elsewhere in Venezuela (Watters, 1971). According to this study, maize yield decreased from 803 kg ha^{-1} to 640 kg ha^{-1} and yucca and bean production fell 60% and 100%, respectively under short fallow systems. Labour which is the only input into the jhum system, used for slash-and-burn of the fallow and for weeding, is in a sense free to the farmer, because it is provided by the farmer's family.

Comparative analysis of jhum (typical version) by three tribes coexisting at lower elevations of Meghalaya

The study area at Lailad, about 70 km north of Shillong, (25.45°N, 91.45°E) is at an altitude of 296 m, and is located in the Khasi hills of Meghalaya, with four communities, namely the Garos, the Khasis, the Mikirs and the Nepalis living together. The area receives an annual average rainfall of 1,435 mm (Maikhuri and Ramakrishnan, 1990a). The rainy season extends from May to October. This is a warm period with high humidity. The average maximum temperature during the season is 35°C and the minimum is 27°C. The mild winter, with an average maximum temperature of 28°C and an average minimum of 17°C extends from November to mid-February. A short dry windy summer from mid-February to May has a maximum temperature of 34°C and a minimum of 23°C.

Jhum as practised by the Garos, the Khasis and the Mikirs living together in the same area at Lailad differed in terms of crop mixtures and the cultivation procedures (Table 1.6). Amongst the communities considered here, the Nepalis, being non-tribal, do not have jhum as a land use. Though mixed cropping is an essential feature of this land use system (Nye and Greenland, 1960; Mutsaers *et al.*, 1981; Ramakrishnan, 1984a), the number

Table 1.6 Major differences in cropping between different communities at Lailad in Meghalaya (from Maikhuri and Ramakrishnan, 1990a)

	Tribal		*Non-tribal*	
Agriculture system	*Garos*	*Khasis*	*Mikirs*	*Nepalis*
Slash-and-burn agriculture	Community labour	Community labour	Family members: stems of larger trees undisturbed	–
Labour for slashing	Stems of larger trees undisturbed	Total slashing		
Crop mixture	10–13	10–13	4–7	–
Sowing time	April	April	February	–
Organic manure input	–	Under 10 and 5 year cycles only	–	–
Weeding	3–4 times	Once	–	–
Harvesting	Sequential (June–December)	Sequential (June–October)	Simultaneous (August–September)	– –
By-products	Left in the plot	Left in the plot	Removed as cattle feed	–
Valley				
Yearly croppings	2	–	1	1
Labour input	Human and animal	–	Human	Human and animal
Organic manure input	Yes	–	Yes	Yes
Weeding	–	–	Once	3 times
Harvesting of crop	July first crop (December for second crop)	–	September	September
By-products	Left *in situ*	–	Removed as cattle feed	Removed as cattle feed

– indicates land use not practised

of crop species are minimal for the Mikirs who are tribes from the plains, and this is suggestive of their affinity to the plains people of the Assam valley who only monocrop rice. The hill tribes, like the Khasis and the Garos, do sequential harvesting of crops but not the Mikirs. Again, the Khasis and the Garos recycle their organic residue into the jhum plots which is characteristic of most hill tribes and unlike the Mikirs (Mishra and Ramakrishnan, 1982). Such differences in the jhum procedures based on socio-cultural affinities of the tribals are significant.

The monetary yield under different jhum cycles essentially followed a similar pattern as the one discussed above. Within a given cycle, however, the Garos obtained more yield from grain and seed crops, and from tuber and rhizome crops compared with the Khasis; the yield was least for the Mikirs (Table 1.7). The net economic return from jhum systems was generally higher for the Garos, which may be largely linked to better

Table 1.7 Mean (± SE) economic yield (kg ha^{-1}) under different jhum cycles of different tribal communities at Lailad in Meghalaya (from Maikhuri and Ramakrishnan, 1990a)

Jhum cycle	*Crop category*			*Grand total*
	Grains and seeds	*Leaves and fruit*	*Tubers and rhizomes*	
20-year				
Garos	2,188 ± 174	370 ± 27	872 ± 68	3,430 ± 238
Khasis	1,920 ± 168	290 ± 22	452 ± 40	2,662 ± 189
Mikirs	1,244 ± 104	74 ± 6	468 ± 37	1,786 ± 154
10-year				
Garos	1,625 ± 131	349 ± 31	988 ± 81	2,962 ± 211
Khasis	1,007 ± 96	401 ± 29	859 ± 56	2,267 ± 169
Mikirs	807 ± 67	141 ± 11	411 ± 33	1,359 ± 133
5-year				
Garos	953 ± 71	374 ± 22	1307 ± 97	2,634 ± 178
Khasis	642 ± 43	495 ± 37	453 ± 32	1,590 ± 128
Mikirs	583 ± 32	403 ± 34	–	986 ± 76

– indicates no data

organization of the crop mixtures by these traditional jhum farmers, with emphasis on grain and seed crops and tuber and rhizome crops.

Comparative analysis of jhum (typical version) of the Nishis and the Hill Miris of Arunachal Pradesh

The study site at Balijan, about 110 km north of Itanagar in Arunachal Pradesh (26.56°N, 93.32°E) is located at an elevation of 200 m. (Maikhuri and Ramakrishnan, 1990b). The climate is typically monsoonic with an annual rainfall of 730 mm, 85% of which occurs during May to September. The average maximum temperature during the summer is 32.6°C and the minimum is 26.2°C; it is 26.5°C and 15.7°C, respectively during the winter.

The Nishis of Balijan in Arunachal Pradesh (200 m altitude) do jhum, more commonly under 5-year cycles, though cycle lengths of up to 60 years may be found in more remote areas (Maikhuri and Ramakrishnan, 1990b). Twenty-five to 33 crop species are grown together. The yield pattern under different jhum cycles remained essentially the same as discussed earlier. Although the return under jhum generally declined with the shortening of the jhum cycle, the net return under a 10-year cycle was higher than under all others (Table 1.8). This is because of the reduced labour costs involved in slash-and-burn operations under a 10-year jhum cycle than under longer cycles on the one hand, and the poor crop yield due to reduced soil fertility under a too short 5-year cycle (Ramakrishnan and Toky, 1981; Gangwar and Ramakrishnan, 1987b; Maikhuri and Ramakrishnan, 1990b). This

Table 1.8 Energy (MJ) and economic (Rupees $ha^{-1} yr^{-1}$) analysis of jhum done by the Nishis in Balijan in Arunachal Pradesh. Monetary values are also presented. (from Maikhuri and Ramakrishnan, 1990b)

	Jhum cycle (yr)									
	60		*30*		*20*		*10*		*5*	
Production measure	*Energy*	*Monetary*	*Energy*	*Monetary*	*Energy*	*Monetary*	*Energy*	*Monetary*	*Energy*	*Monetary*
Inputs										
Labour	2,788	4,624	2,231	3,650	1,543	2,980	1,155	2,740	819	2,186
Seed	67	32	63	38	56	36	39	26	34	29
Total	2,855	4,658	2,294	3,888	1,599	3,016	1,194	2,766	853	2,215
Output										
Grain and seed	51,639	5,532	47,425	5,058	38,874	4,137	33,075	4,377	9,585	1,110
Leaf and fruit vegetables	3,555	338	4,171	396	4,772	454	6,984	560	6,889	563
Tuber and rhizome	11,977	1,560	9,243	1,203	7,281	1,043	10,643	1,527	18,581	2,663
Total	67,171	7,430	60,839	6,657	50,927	5,634	50,702	6,464	35,055	4,336
Output/input ratio	24	1.6	27	1.7	32	1.9	43	2.3	41	2.0

essentially implies that a 10-year cycle is the cut-off length from the point of economic efficiency as shown in this study (Maikhuri and Ramakrishnan, 1990b) and as observed in our earlier studies (Toky and Ramakrishnan, 1981a).

The hill Miris of Arunachal Pradesh living at Raga (27.44°N, 93.51°E) at an altitude of about 1,000 m also practise the typical version of jhum under 7- to 10-year jhum cycles (Kumar and Ramakrishnan, 1989a). The output total is somewhat lower than the jhum under comparable cycles done by the Nishis.

Jhum (typical version) practised by the Khasis at mid-elevations of Meghalaya

The study site at Nayabunglow (25.45°N and 91.54°E) at an altitude of 910 m in the Khasi hills of Meghalaya is about 30 km north of Shillong. The climate is typically monsoonic with over 80% of the total annual rainfall of 1,800 mm occurring during May–September (Patnaik and Ramakrishnan, 1989). The monsoon is followed by winter during October–February. March and April represent a brief warm dry period. The mean monthly maximum and minimum temperatures during the monsoon are 28.6°C and 17.1°C, respectively and for the winter, they were 21.3 and 3.9°C, respectively.

At Nayabunglow, the Khasis practise jhum under cycle lengths of 5–10 years (Patnaik and Ramakrishnan, 1989), the emphasis here being exclusively on tuber, root and vegetable crop species, such as ginger, *Colocasia antiquorum*, *Ipomoea batatus*, *Capsicum frutesence* and cucurbits. This shift in emphasis towards tuber crops is related to the sharp reduction in soil fertility under short cycles at this elevation where soil fertility recovery is slower under the cooler climate. The Khasis obtain higher economic returns (Table 1.9) through this shift towards more nutrient-use efficient tuber/root crops, as also seen from many other studies (Toky and Ramakrishnan, 1981a; Ramakrishnan, 1984a). Indeed, the monetary output total under 10-year jhum cycles here is six times higher than that under the jhum practised by the Garos at lower elevations of Meghalaya (cf Table 1.4).

Modified version of jhum of the Khasis at higher elevations of Meghalaya

In the mixed cropping system used on the slopes prepared into ridges and furrows, the major crop grown by the Khasis at Shillong was rice, until a few decades ago. But when the British introduced potato as a crop into this region towards the turn of this century, it became a popular crop very rapidly, although rice is still the staple diet of the local tribe, and is frequently grown.

Table 1.9 Monetary (Rupees $ha^{-1} yr^{-1}$) analysis of jhum of the Khasis at Nayabunglow in Meghalaya (from Patnaik and Ramakrishnan, 1989)

	Jhum cycle (yr)		
	5	*7*	*10*
Input total	7,431	9,693	10,548
Human labour	4,800	6,154	6,902
Bullock power	–	–	–
Seed	2,631	3,539	3,646
Inorganic fertilizer	–	–	–
Output total	7,520	14,194	18,370
Output/input ratio	1.01	1.46	1.74

At higher elevations, where the pine trees are sparsely distributed, slash-and-burn with clear-felling of the forest is not feasible because of slower forest regeneration capabilty of the site under the sub-temperate climate. (Mishra and Ramakrishnan, 1983a). The preparation of the site into alternate ridges and compacted furrows running down the slope with the compacted furrows acting as water channels would help in conserving nutrient losses through water (Mishra and Ramakrishnan 1983c), which could, otherwise, be higher. This is particularly important because the soil fertility recovery is slower at these elevations (Mishra and Ramakrishnan, 1983b,d) and the soil under pine forests is highly acidic, further aggravating the nutrient availability (Ramakrishnan and Das, 1983; Das and Ramakrishnan, 1985). Burning the limited slash that is available after stacking in parallel rows, and slow burning of the dried slash, after topping it over with a thin soil layer to form the ridges, is an efficient way of resource management. The nutrient enriched furrows alone then are used to support crop growth. In such a situation of generally reduced soil fertility level that becomes further aggravated by the shortened jhum cycle of 4–5 years, the shift towards tuber crops that can give better economic yield in nutrient poor soils (Ramakrishnan, 1984a), is understandable. No wonder that when potato was introduced a few decades ago, it rapidly became popular.

A comparative analysis of the modified version of jhum carried out by the Khasis under varied cycle lengths shows that the economic returns are very high, although the yield declines with shortening of the jhum cycle (Table 1.10). The monetary return under a 10-year jhum cycle (Table 1.11) is about 5-times more than that under a similar cycle length done at lower elevation (cf Table 1.5).

This high net monetary return and economic efficiency (output/input ratio) is in spite of the high input required for land preparation in the high elevation modified system. Potato which has higher monetary value is largely produced for export from the village ecosystem.

Table 1.10 Economic yield of crops (kg ha^{-1} yr^{-1} oven dry wt) (± SE) under different jhum cycles of the Khasis at Shillong in Meghalaya (from Mishra and Ramakrishnan, 1981)

	Jhum			
Crop species	*15-yr cycle*	*10-yr cycle*	*1-yr crop*	*11-yr crop*
Root and tuber crops				
Solanum tuberosum	1,579.95 ± 23.75	1099.10 ± 5.55	748.76 ± 2.29	449.25 ± 1.86
Ipomoea batatus	444.78 ± 7.85	148.26 ± 2.10	-	-
Colocasia antiquorum	4.87 ± 0.27	5.57 ± 1.91	-	-
Cereals				
Zea mays	42.35 ± 1.07	59.29 ± 1.92	61.62 ± 1.39	8.57 ± 0.31
Oryza sativa	-		-	-
Legume				
Phaseolus vulgaris	6.66 ± 0.27	3.99 ± 0.26	-	-
Fruit vegetables				
Cucurbita maxima	272.43 ± 3.67	257.55 ± 1.95	-	-
Cucumis sativus	9.08 ± 0.58	6.31 ± 0.35	-	-
Leafy vegetables				
Brassica oleracea	76.48 ± 2.11	27.41 ± 1.29	163.90 ± 1.42	50.25 ± 1.88
Colocasia antiquorum	2.38 ± 0.13	2.47 ± 0.15	-	-
Cucurbita maxima	3.09 ± 0.24	2.79 ± 0.27	-	-
Ipomoea batatus	0.98 ± 0.07	1.13 ± 0.15	-	-
Other vegetables				
Colocasia antiquorum (stem)	0.44 ± 0.02	0.41 ± 0.02	-	-
Cucurbita maxima (flower)	0.41 ± 0.02	0.47 ± 0.03	-	-
By-products				
Oryza sativa (straw)	-	-	-	-

- indicates absence

Table 1.11 Cost–benefit analysis (Rupees ha^{-1} yr^{-1}) for different jhum systems of the Khasis at Shillong in Meghalaya (Mishra and Ramakrishnan, 1981)

	Jhum cultivation			
			5-yr cycle	
Production measures	*15-yr cycle*	*10-yr cycle*	*1st yr crop*	*2nd yr crop*
Inputs				
Labour	2,220	2,049	1,613	1,604
Organic manure	–	175	287	537
Fertilizer	–	–	19	39
Seed	1,061	1,206	1,235	1,254
Interest on working capital (12%)	394	412	378	412
Output				
Root and tuber crops	14,711	9,875	6,463	3,914
Cereal grains	65	90	94	13
Legumes	16	9	–	–
Fruit and other vegetables	4,220	3,908	–	–
Leafy vegetables	778	289	1,631	500
By-products	–	–	–	–
Cost of production (a)	3,675	3,842	3,532	3,846
Gross return (b)	19,790	14,171	8,188	4,427
Net return (b – a)	16,115	10,329	4,656	581
Return per rupee	5.4	3.7	2.3	1.2

Conclusions

Cropping and yield patterns under jhum vary considerably, as seen from the preceding pages. Partly this is related to the ecological, socio-economic and socio-cultural background where the system operates. Thus for example, the Garos being hill tribesmen are better organized jhum farmers than the Mikirs at Lailad, because the latter are basically plains tribesmen of the Assam valley.

The length of the jhum cycle has been drastically shortened during the recent past with a 4–5-year cycle length being more common, though a 60-year cycle could be rarely found as for the Nishis of Arunachal Pradesh. It is interesting to find a shift towards tuber/rhizomatous crops under shorter cycles; this was seen for the Garos at Burnihat in Meghalaya and for the Nishis of Arunachal Pradesh. Such distantly placed tribes showing a similarity in shift of the cropping pattern under shortening jhum cycles suggests that the farmers, based upon empirical knowledge collected over a period of time, adapt the crop mixture in a manner to maximize production. They find, for example, that certain crop species are more appropriate under reduced fertility status in the soil – in this case tuber and rhizome crops under short jhum cycles (Ramakrishnan, 1984a). Such a shift to tuber crops by the Khasis at higher elevations is also a response to the ecology of the area.

With a highly heterogeneous social environment, with many tribes coexisting in the same area, or tribes changing over short distances, wide variations occur for the yield pattern under jhum, which is related to crop mixtures used and cropping pattern itself. It follows from this that often by mere manipulation of crop mixture, one could improve the yield from the jhum system, as seen from the discussion here. However, it is important to keep a minimum cycle length of 10 years if the system, as it functions now, is to be economically viable.

ENERGY BUDGET UNDER JHUM

Apart from economic yield of crops and monetary cost–benefit analysis, energy budgets and efficiences provide one of the many ways to evaluate agroecosystem function. Fossil energy (fertilizer, fuel, etc.) land and labour are the three major resources for modern agriculture. These three are related to one another and could compensate, at least in part, one for the other.

In the jhum system under consideration here, fossil fuel energy is not normally used except where the cycle is short and soil fertility very low. Land is a limiting factor to the extent that with reduced land area and increased population pressure, the farmer resorts to shortened jhum cycles (Ramakrishnan, *et al.*, 1981a,b). Labour input is from within the family, except for labour intense activities where labour is provided collectively, a few families joining together. Soil fertility is maintained through natural processes of forest fallow regrowth during secondary succession (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983d). The present study analyses the energy budget under different jhum systems with varied inputs in terms of labour, land availability that determines jhum cycle and organic fertilizer input. The energy efficiency (output/input ratio) of the different jhum systems in relation to these components and the crop mixtures used is evaluated.

Energy budget under different cycles of typical jhum

In a comparative analysis of the jhum system of the Garos under 30-, 10-, and 5-year cycles at lower elevations of Meghalaya, we considered in detail the implications of energy budget under shortening jhum cycles (Toky and Ramakrishnan, 1982a). A major conclusion arising from this comparative analysis is that jhum in the hill areas of north-eastern India has survived all these years chiefly because of the high energy efficiency of the system associated with longer cycles where the only energy input is in the form of

Table 1.12 Energy inputs (MJ ha^{-1} yr^{-1}) for agriculture under different jhum cycles of the Garos in Burnihat in Meghalaya (from Toky and Ramakrishnan, 1982a)

	Energy input (MJ ha^{-1} yr^{-1}) *under jhum*		
Agricultural operation	*30-yr cycle*	*10-yr cycle*	*5-yr cycle*
Labour input (total)	1,641	1,176	494
Clearing understorey vegetation	274	331	78
Felling trees and bamboos	583	319	–
Collection of debris and burning	51	35	5
Terrace preparation	–	–	–
Dibbling broadcasting and transplanting	40	43	43
Hut construction	23	24	24
Weeding	63	76	87
Guarding the field from wild animals	71	70	64
Rearing caterpillars	123	–	–
Harvest	187	198	173
Transportation	21	13	8
Threshing	77	25	5
Shelling	128	42	7
Seed input	24	15	16
Fertiliser	–	–	–
Total energy input into the system	1,665	1,191	510

manual labour which is provided by the farmer, a major fraction of which goes for slash-and-burn operation (Table 1.12). Further, this labour input is uniformly distributed throughout the year as shown by us in one of the studies on the Khasis working under a 5-year jhum cycle (Fig 1.1) (Patnaik and Ramakrishnan, 1989). According to Rappaport (1971), the 'Tsembaga' people of the New Guinea Highlands obtained an average of 16 units of food energy for each unit of human energy employed during farming; this may increase to 20 under more favourable conditions. Others have reported equally high, or even higher, efficiency values with output/input ratios of up to 54 (Lewis, 1951; Norman, 1978; Uhl and Murphy, 1981).

Most of these studies, however, do not mention the length of the jhum cycle and its relationship to energy efficiency. Our study of three jhum cycles of 30, 10, and 5 years give different energy input and output patterns, as well as overall efficiency values for the system (Table 1.13). This is understandable in view of the fact that the labour energy input into the system varies for the following reasons: Firstly, the bamboo/dicotyledonous tree dominated fallow slashed under long cycles involves greater expenditure of energy compared with the weedy herbaceous growth slashed under a 5-year cycle, secondly, the energy expended on weeding increased with

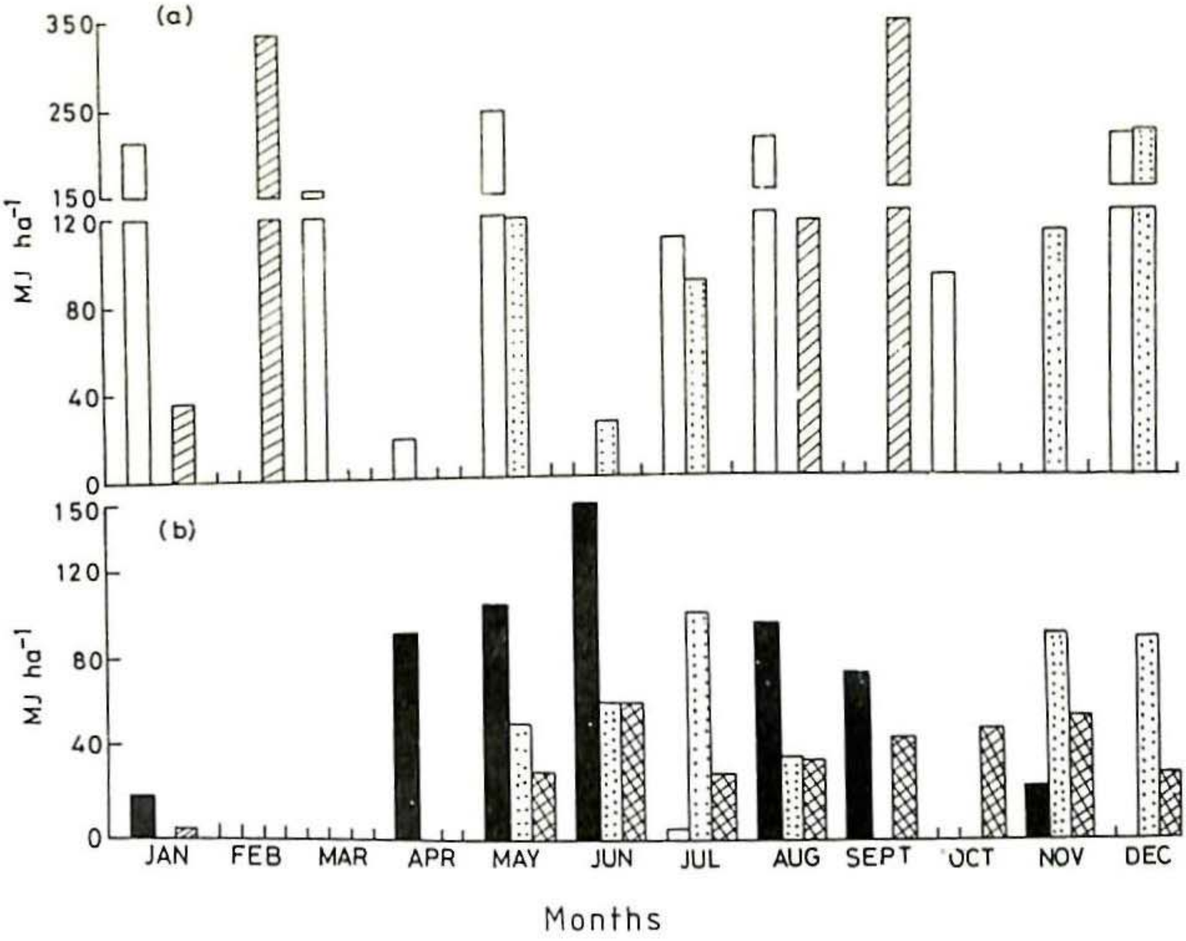


Figure 1.1 Distribution of labour over a year under jhum of the Khasis compared with other land use systems of the Khasis (a) another Nepalis (b) at Nayabunglow in Meghalaya. □, 5-year jhum cycle, ░, valley cultivation; ▨, pineapple plantation; ▩, kitchen garden; ■, fodder grass cultivation (from Patnaik and Ramakrishnan, 1989)

Table 1.13 Energy ratio for agriculture under diffferent jhum cycles of the Garos in Burnihat in Meghalaya (Toky and Ramakrishnan, 1982a)

	Energy (MJ ha^{-1} yr^{-1})		*Output/input*
Agriculture system	*Input*	*Ouput*	*ratio*
Jhum			
30-year cycle	1,665	56,766	34.1
10-year cycle	1,191	56,601	47.5
5-year cycle	510	23,858	46.7

shortening of the jhum cycle as the weed problem is aggravated here (Saxena and Ramakrishnan, 1984b) so much so that the secondary succession is often arrested at the weed stage under a 5-year cycle (Toky and Ramakrishnan, 1983a), and finally, considerable reduction in yield occurred under a 5-year cycle, partly related to poor nutrient recovery during the short fallow phase (Ramakrishnan and Toky, 1981) and more severe weed problem as mentioned above.

Table 1.14 Energy input and output (MJ ha^{-1} yr^{-1}) under different jhum cycles of different tribal communities at Lailad in Meghalaya (from Maikhuri and Ramakrishnan, 1990a)

	Production measures					
		Output				
Jhum cycle	*Input*	*Grains and seeds*	*Leaves and fruit*	*Tubers and rhizomes*	*Total*	*Output/ input ratio*
20-year						
Garos	1,688	41,089	5,846	13,342	60,277	35.7
Khasis	1,352	37,487	4,582	6,916	48,985	36.2
Mikirs	1,043	24,649	1,169	7,160	32,978	31.6
10-year						
Garos	1,200	31,509	5,517	15,116	52,142	43.4
Khasis	1,659	18,065	6,336	13,143	37,544	22.6
Mikirs	794	14,642	2,228	6,288	23,158	29.0
5-year						
Garos	810	18,852	5,909	19,997	44,758	55.2
Khasis	1,470	11,934	7,821	6,931	26,686	18.1
Mikirs	546	9,462	6,367	–	15,829	29.0

– indicates no data

In another study carried out on the Nishis of Balijan at Arunachal Pradesh (Maikhuri and Ramakrishnan, 1990b), we compared energy efficiencies of jhum cycles of 60, 30, 20, 10 and 5 years, and found that a too long jhum cycle such as a 60-year one is less efficient (Table 1.8). The major disadvantage of a 60- or even 30-year cycle lies in the high labour energy input needed for slash-and-burn of a denser secondary forest. This would explain the more favourable output/input ratio of the jhum system, under a 10-year cycle compared to all others, including the 5-year cycle where the low output reduced the efficiency.

Comparative energy analysis of jhum systems of different tribes

A comparative analysis of energy efficiency (output/input ratio under the typical version of the jhum as practised by different tribes living is the same area in the north-eastern region showed wide variation (Table 1.14). Between the Garos, the Khasis and the Mikirs living in the same area, at Lailad at lower elevations (296 m) of Meghalaya the Garos have higher efficiency values (Maikhuri and Ramakrishnan, 1990a). However the Khasis, operating at Nayabunglow at mid-elevations of Meghalaya (960 m), with less variety in crop mixture, growing exclusively tuber and rhizomatous crops, obtain very low energy efficiencies for their system (Patnaik and Ramakrishnan, 1989). The energy efficiency for the Nishis of Arunachal Pradesh (Maikhuri and Ramakrishnan, 1990b) is generally comparable to that of the Garos at lower elevations of Meghalaya. Such wide variation between tribes, even under comparable jhum cycles, could often be largely linked with variation in the emphasis on the crop mixture, particularly when the communities live in the same area. If they are from different areas, labour expended in land preparation and differences in the ecology of the area could also be factors.

Energy budget under modified jhum at higher elevations of Meghalaya

The broad generalizations about the typical version of jhum discussed above also apply to the modified version of the high elevation system (Mishra and Ramakrishnan, 1981) except for a major difference in the energy budget. The output/input ratios for jhum here are generally lower with values of 26, 10, and 5 for 15-, 10-, and 5-year jhum cycles, respectively. This is because of a heavier labour input for land preparation into ridges and furrows and also because of organic (pig dung and vegetable compost) and inorganic (NPK, 1:1:1) fertilizer inputs which could be at the rate of 1,000 kg ha^{-1} and 10 kg ha^{-1}, respectively during the first year of cropping under a 5-year jhum cycle. During the second year of cropping, which is usually done, these quantities almost double. Under a 10-year jhum cycle, these quantities may be lower than that under a 5-year cycle. Such a high input of energy for cropping is necessitated by poor soil fertility at higher elevations, because of lower temperature that slows down soil fertility recovery processes (Mishra and Ramakrishnan, 1983d), higher soil acidity under pine, and slowly decomposing pine litter. Indeed, in a study of the modified version of the jhum system near Shillong involving potato as the major crop but with variations in the mixture of other crop species under 15-, 8-, and 5-year jhum cycles, the energy ratio (output/input) varied between 3.6 and 9.8, which is very low indeed (Gangwar and Ramakrishnan, 1987a).

In this jhum system, as also in all others discussed earlier, women play an important role in jhum operations. Only heavy labour such as that for slash-and-burn is shared by men. Figure 1.2 shows the allocation pattern of labour between males and females for a 5-year jhum cycle of the modified version as done by the Khasis, which was generally the same for longer cycles too. More than 65% of the work was done by the female members of the family. However, the work done by both male and female members for the initial operation of slashing of understorey vegetation was more or less the same. While preparation of land into ridges and furrows along with burning and seed sowing operations was an exclusively female function, weeding and maintenance of the field was almost equally shared between male and female members. The implications of these results are obvious. In any consideration of the jhum system, the viewpoints of the female

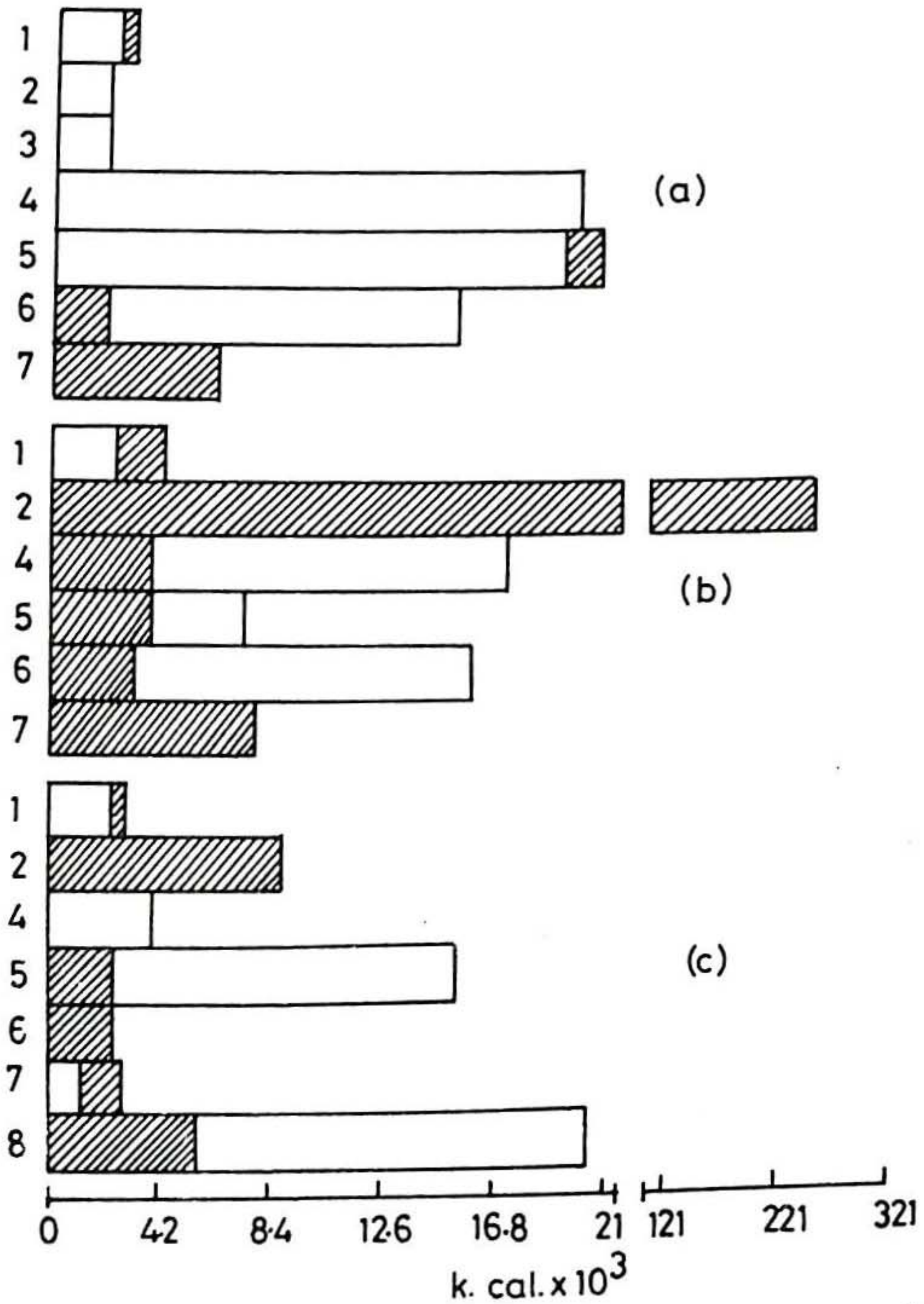


Figure 1.2 Allocation pattern of labour between male and female members of the Khasi family under jhum compared with other land use systems at Shillong in Meghalaya. a, 5-year jhum cycle; b, terrace agroecosystem; c, valley agroecosystem; hatched column, male labour; open column, female labour; 1, clearing the vegetation; 2, land preparation; 3, burning; 4, seed sowing; 5, weeding and field maintenance; 6, harvesting; 7, transportation; 8, threshing and milling (from Mishra and Ramakrishnan, 1981)

members of the society should find adequate consideration. We shall consider this further in our subsequent discussions.

Conclusions

Energy in relation to land under jhum

The comparative energy efficiency of the jhum cycles cannot be considered in isolation but needs to be discussed in relation to the land use pattern or else energy efficiency values *per se* could lead to a distorted comparison for different jhum cycles (e.g., 5-year cycle versus a 10- or 30-year cycle). The studies of Toky and Ramakrishnan (1982a) for example, indicate the trade-off between land area and energy input. If land is not a limiting factor, then the greater input to a larger area of the jhum system with a longer cycle could be used to offset imported energy and this would ensure harmony of the long cycle with the environment, at the same time ensuring rational returns to the farmer. However, with increase in population pressure and decrease in acreage available for jhum, due to environmental degradation with permanent weedy communities of arrested succession or even extreme desertification (Ramakrishnan, 1985d; Ramakrishnan *et al.*, 1981a,b), land is in short supply, resulting in very short jhum cycles of 4–5 years. In such a situation, the longer the jhum cycle, the larger the area of land that is needed, although effective output per hectare would decrease due to a correction factor of $^1/_{30}$, $^1/_{10}$ or $^1/_5$ for jhum cycles of 30, 10 and 5 years so that an effective output of only 1,892, 5,660 or 4,772 MJ per hectare is obtained (cf Table 1.13). On this basis too, a 10-year jhum cycle is the most efficient in terms of energy ratio and land use. Similar conclusions emerge from our other studies of jhum systems in the north-eastern region considering in one instance cycle lengths ranging between 5 and 60 years (Maikhuri and Ramakrishnan, 1990b).

Energy efficiency and sustainability of jhum

With relatively high energy efficiency, jhum under a 10-year cycle is sustainable. However, wide variations exist in the energy efficiency of jhum practised by different tribes in the same area. Efficiency in jhum operations such as slash-and-burn, sowing practices, weed management and crop organization, all contribute to overall energy efficiency. The variations that are available could be exploited for improving this land use, for the benefit of the farmer. Indeed certain crops such as *Flemingia vestita* used by jhum farmers at higher elevations of Meghalaya (Gangwar and Ramakrishnan, 1989b) could even replace the input of fertilizer required under shorter cycles. This is because of the nitrogen fixed by this legume when included in the crop mixture.

IMPLICATIONS OF MIXED CROPPING UNDER JHUM

A high species diversity is characteristic of many tropical agroecosystems (Whittaker, 1972, 1975). Such a high species diversity, as under jhum (Plate 1.6) contributes to agroecosystem stability. With a multilayered canopy and with a high leaf area index for efficient light capture and a layered root mass distribution in the soil profile for optimal nutrient use, crop

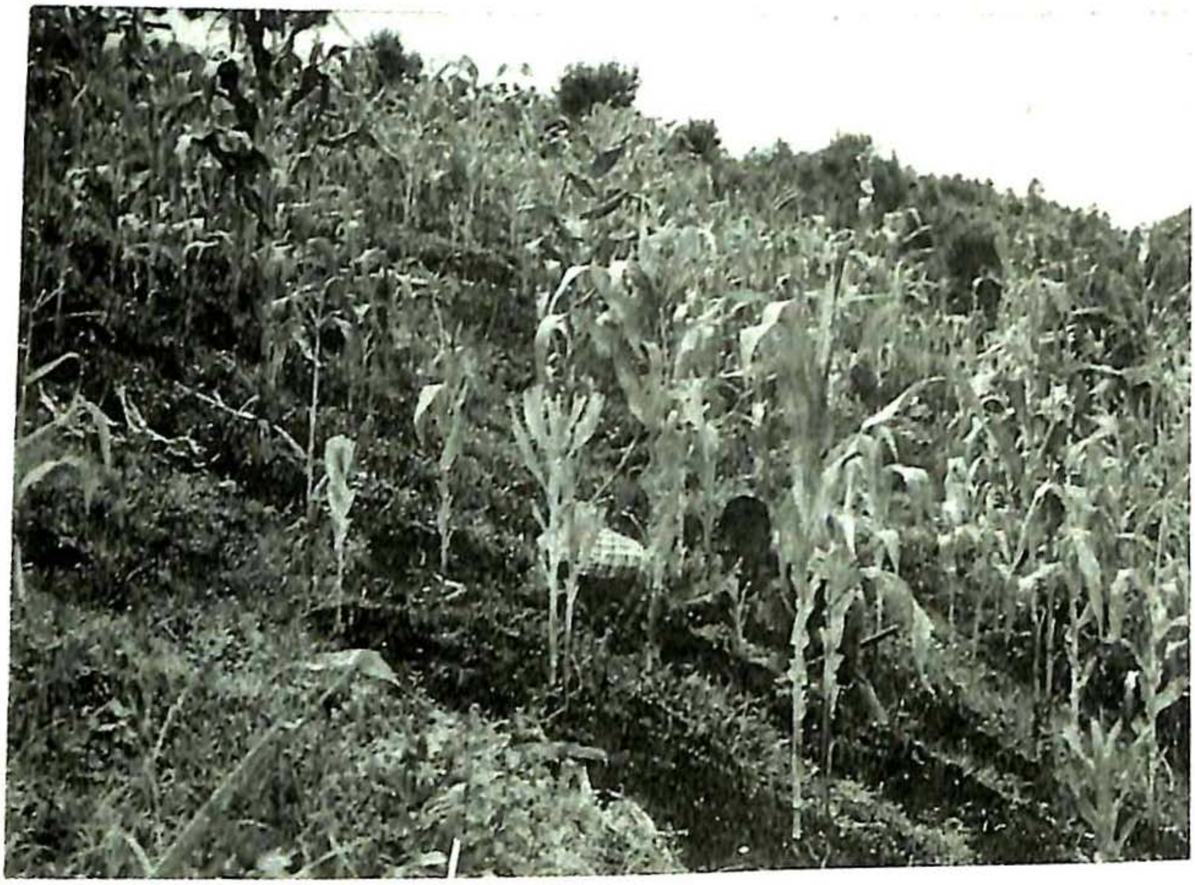


Plate 1.6 A jhum plot at Shillong (1,500 m) in Meghalaya under mixed cropping. *Zea mays* is clearly visible on the ridges. Potato has already been harvested by the Khasi farmer. This mixed cropping system with species grown on the ridges has compacted furrows running down the slope acting as water channels

productivity is usually high (Table 1.15). The values for the primary productivity under jhum in north-eastern India (Toky and Ramakrishnan, 1981a) compare with those of the secondary successional fallows up to 20 years in the same area (Toky and Ramakrishnan, 1983a).

A characteristic feature of jhum is the high rate of biomass accumulation in relation to economic output. The high rates of organic matter production measured under jhum (16–22 tons ha^{-1}) are close to values obtained from natural plant communities (14.8 tons ha^{-1}) for 20-year-old forest fallows in the same area of north-eastern India. With higher crop diversity, it should be possible to combine the need for increased harvestable food production with the need for maintaining high organic biomass content in the system as a whole (Trenbath, 1974). Without this high organic matter production it would become necessary to constantly import costly inorganic fertilizers which are hard to come by and whose effectiveness in the face of high temperature and heavy rainfall is questionable (Gliessman, 1980; Gliessman *et al.*, 1981; Ramakrishnan *et al.*, 1981a,b), particularly when the soil is extremely porous contributing to heavy infiltration losses (Toky and

Table 1.15 Economic yield and community traits for agriculture under different cycles for the Garos at Burnihat in Meghalaya (from Toky and Ramakrishnan, 1981a)

	Fallow period (yr)		
	5	*10*	*30*
Economic yields (tons ha^{-1} yr^{-1})			
Seeds	0.107	1.153	2.180
Leaf fruit	0.129	0.074	0.024
Tubers	0.320	0.613	0.192
Total	0.556	1.840	2.396
ANP	14.060	11.576	15.213
Growth rate (g m^{-2} day^{-1})	3.8	3.2	4.2
NPP	18.461	14.709	17.746
Growth rate (g m^{-2} day^{-1})	5.1	4.0	4.9
Number of cultivars	8	12	14
LAI	0.59	1.49	3.20
HI	0.030	0.125	0.135
HI (grain + seed)	0.184	0.230	0.182
Labour (days ha^{-1} yr^{-1})	149	305	436

ANP = annual net production
NPP = net primary productivity
LAI = leaf area index

HI = Crop yield/NPP because seeds, leaves and tubers are harvested
HI (grain + seed) = above ground crop yield/ANP

Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983c). Being a no-tillage agroecosystem, substantial organic matter (Mishra and Ramakrishnan, 1982) is conserved and is comparable to old-field natural plant communities (Ramakrishnan, 1988a; Toky and Ramakrishnan, 1983a, Stinner *et al.*, 1983).

Sequential harvesting of crops is an effective way of managing up to 35–40 crop species over both space and time. Thus after harvesting early maturing species such as 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 perennial crops, which also receive humus and nutrients (Ramakrishnan, 1984a). Such an efficient recycling of organic crop residues may be illustrated for an important nutrient such as nitrogen. The amount of nitrogen ploughed back as by-products into the system during one cropping season amounts to 0.6–0.8 kg ha^{-1} depending upon the jhum cycle, at higher elevations of Meghalaya (Mishra and Ramakrishnan, 1984). Under a 15-year jhum cycle, this amounts to $^{1}/_{6}$th of the total of 4.1 kg ha^{-1} yr^{-1} of nitrogen through non-edible biomass which goes into the jhum system either directly or through the manure pit in the village (Mishra and Ramakrishnan, 1982).

Mixed cropping as practised in this traditional agroecosystem is receiving considerable attention from modern agricultural scientists as a biological pest suppressant (Litsinger and Moody, 1976). The use of native varieties would probably ensure that a high degree of natural chemical defences are maintained (Janzen, 1973). Further, under mixed cropping, it is unlikely that any one of the pest populations of insects, fungi, bacteria or nematodes would reach epidemic levels due to high genetic diversity.

On a steep slope of 30–40° angle, the soil nutrient environment is very transient. One of the important objectives of the jhum farmer, therefore, is to capitalize upon the highly transient resource base as quickly and effectively as possible through a mixed cropping system. Maximizing economic yield in such a transient environment is critical. The jhum farmer ensures effective use of the nutrient gradient on the steep hill slope by emphasizing upon species that have a high nutrient-use efficiency along the nutrient-poor top of the slope and by organizing less use-efficient species along the nutrient-rich base of the slope (Ramakrishnan, 1984a). By this he is able to achieve a high leaf area index for optimizing photosynthesis and maximizing economic yield.

Erosion from plots being a major cause for loss of sediment and nutrients could be effectively countered by good soil cover afforded by the crop vegetation. Under longer jhum cycles, the losses of nutrients become minimized (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983c) with a consequent higher soil fertility status (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983d). This is partly because there is more than a doubling of soil cover by the crop from 10-to 30-year jhum cycles and over a five-fold increase from 5- to 30-year cycles (Table 1.15). In the ultimate analysis, mixed cropping maximizes production, minimizes losses, provides a wide food resource base for the tribal society by providing cereals, legumes, vegetables and even fibre, and at the same time ensures leisure by effectively spreading out labour all the year round.

GENERAL CONSIDERATIONS

One of the major problems with jhum in north-eastern India, as is also true elsewhere, is the drastic shortening of the jhum cycle to 4–5 years during recent years. This has adversely affected economic yield with gradual decline in yield over a period of time when short cycles are imposed (Fig 1.3).

Jhum as practised in the north-eastern hill region of India is a highly complex system, with wide variations based on cropping and yield pattern. These variants, based on ecological, social and cultural variations in the tribal societies, are highly insulated because of topographical and language barriers. Yet these jhum systems may markedly differ from each other in

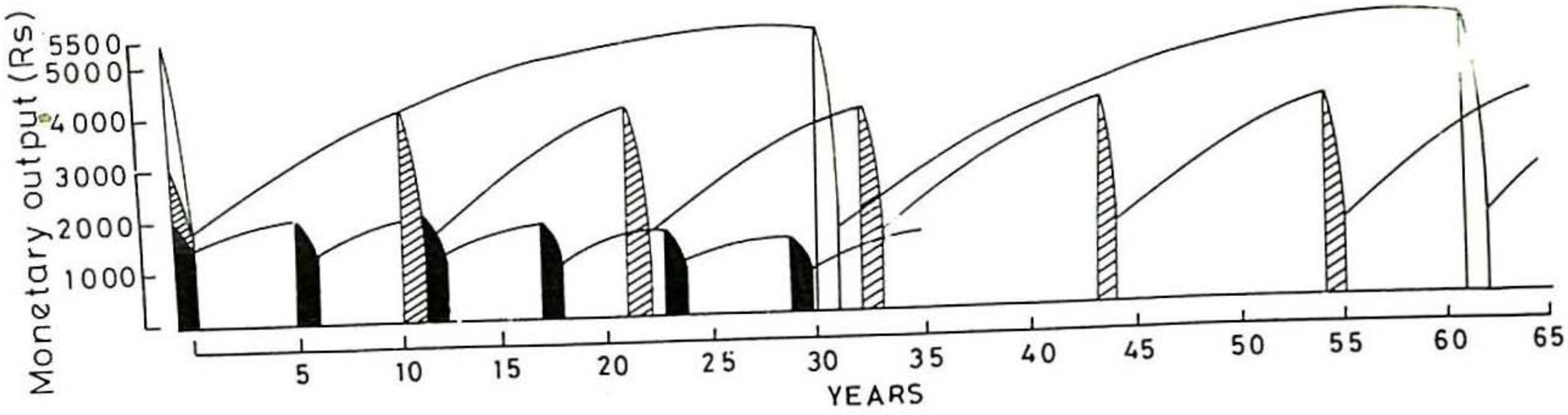


Figure 1.3 Economic yield pattern under different jhum cycles of 30 (□), 10 (▨), and 5 (■) years, over a period of time, at Burnihat at lower elevations of Meghalaya (from Ramakrishnan, 1985c)

terms of their economic and energy efficiencies. It is in this context that transfer of traditional technology from one tribal community to another in terms of crop organization and crop management becomes important. Often, by mere manipulation of the crop mixture, the economic returns to the farmer could be increased many-fold. This approach offers an important channel for redeveloping jhum, without any additional input from outside technology to strengthen it, provided a reasonable cycle length could be ensured.

On the basis of our economic and energy analysis of the jhum system, a 10-year jhum cycle is the minimum cycle length, if jhum in the present form is to be sustained. Therefore, wherever a minimum cycle length of 10 years is feasible mere manipulation of the crop mixture discussed above may prove to be adequate. It is when the cycle length comes down to a more common and very short 4–5 years, as at present, that distortions set in and the system starts breaking down. In such a situation, one is left with two options: one, take the pressure off the land for jhum by strengthening alternate land use systems discussed in the next chapter, or alternatively, and two, to stabilize jhum under a 5-year cycle by strengthening the agroforestry inputs as discussed elsewhere.