# Shifting cultivation and forest resources in Nagaland, N.-E. India

Maike Krug

# Shifting cultivation and forest resources in Nagaland, N.-E. India

Maike Krug

Dissertation presented to the Faculty of Organic Agricultural Sciences / Department of Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics

University of Kassel

2009

Die vorliegende Arbeit wurde vom Fachbereich Agrarwissenschaften der Universität Kassel als Dissertation zur Erlangung des akademischen Grades eines Doktors der Agrarwissenschaften (Dr. agr.) angenommen.

Erster Gutachter: Prof. Dr. Andreas Bürkert
Zweiter Gutachter: Prof. Dr. Eva Schlecht

Tag der mündlichen Prüfung: 10. Juli.2009

This work has been accepted by the Faculty of Organic Agricultural Sciences of the University of Kassel as a thesis for acquiring the academic degree of Doktor der Agrarwissenschaften (Dr. agr.).

1$^{st}$ Supervisor: Prof. Dr. Andreas Bürkert
2$^{nd}$ Supervisor: Prof. Dr. Eva Schlecht
Examiner: Prof. Dr. Achim Dohrenbusch
Examiner: Dr. Martin Worbes

Defense date: 10$^{th}$ July 2009

## Table of Contents

**Summary:**

**Shifting cultivation and forest resources in Nagaland, N.-E. India**

Our study discusses a traditional shifting cultivation system, Jhum, in two remote villages of Nagaland, North-East India (Hongphoy and Minyakshu) under aspects of subsistence livelihood needs (cereal production and firewood collection), environmental impacts (forest and soil degradation) and population growth. While the traditional land management by slash and burn agriculture of the remote and formally headhunting tribes of the Naga was fulfilling the needs of the population since decades, our interviews and field surveys conducted in two contrasting villages in 2004 and 2005 revealed that the increasing demand on cereals and fuelwood by an increasing population lead to shortened Jhum cycles and the degradation of natural resources: per ha yields are reduced and the stock volume of fallow fields can not produce sufficient amount of firewood due to shortened fallow periods.

The relation between the average annual harvest per caput and the caloric demand allows quantifying a caloric intake shortage under consideration of the means and availability of purchasing food from outside. A village level food gap of 130 t of rice in Hongphoy and of 480 t in Minyakshu was revealed. This already delicate food situation is further aggravated by an annual population growth of 6.7%.

The study of five forest stands (two Jhum fallow forests, two village forests and one natural forest) revealed large differences in species composition (stand diversity) and volume of standing stock.

The per head fuelwood demand was assessed and related to available stock volumes from fallow forests, resulting in a gap of 1.81 $m^3$ in Hongphoy and 0.05 $m^3$ in Minyakshu that has to be covered within other forest resources not subject to shifting cultivation. The difference between the two villages is explained by a differing stand composition and the management of stand improving, $N_2$-fixing tree species *Alnus nepalensis* in the latter village. The existing demand for fuelwood was further related to a theoretical per caput fallow forest area requirement for satisfying the fuelwood needs solely on fallow fields. The study indicated that fuelwood collection and shifting cultivation are major causes of deforestation and forest degradation in Nagaland.

By those information and the current population growth figures, the study compares human demands for cereals and firewood with actual crop yields and firewood harvests from Jhum fields and discusses the results in the light of literature data. In this way, the carrying capacity of Jhum systems in this specific region of North-East India is determined, consequences of the typically low grain yields from shifting cultivation on food security are analysed, and potential adaptation strategies to increasing resource degradation and scarcity are elaborated.

**Deutsche Zusammenfassung:**

## Wanderfeldbau und Forstressourcen in Nagaland, N.-O. Indien

Die vorliegende Studie befasst sich mit der Ressourcennachhaltigkeit der traditionellen, auf Wanderfeldbau beruhenden Subsistenzwirtschaft in zwei Dörfern (Hongphoy und Minyakshu) in Nagaland im Nordosten Indiens. Hierbei werden die Cerealien Produktion, der Feuerholz Konsum und auch die Folgen der intensivierten Bewirtschaftung (Forstdegradation und Bodenverarmung) im Hinblick auf das Bevölkerungswachstum diskutiert. Während das traditionelle System des Wanderfeldbaus (Jhum) seit Jahrzehnten die Bedürfnisse der ehemals kopfjagenden Stämme Nagalands erfüllte, ergab unsere Studie durch Interviews und Feldaufnahmen in 2004 und 2005, dass die steigende Nachfrage einer wachsenden Bevölkerung nach Cerealien und Feuerholz als wichtigste Ressourcen der Subsistenzwirtschaft zu einer verkürzten Brachezeit und letztlich der Degradation von Naturressourcen geführt hat: Pro Hektar Ernten sind reduziert und der Zuwachs der Holzvorräte auf den Feldern kann durch die verkürzten Bracheperioden nicht mehr die Feuerholz Nachfrage decken.

Eine Nahrungsmittelknappheit wurde durch die Gegenüberstellung des Energiebedarfs einer Person und die jährlichen pro-Kopf Erntemengen und unter Berücksichtigung des Zukaufs von Reis reflektiert: In Hongphoy ergab dies ein Defizit auf Dorfebene von 130 Tonnen Reis, in Minyakshu von 480 Tonnen, die nicht durch Ernten gedeckt werden konnten. Diese Nahrungsmittelknappheit erweist sich vor allem vor dem Hintergrund eines Bevölkerungswachstums von 6.7% und marginalen Einkünften als problematisch.

Für fünf verschiedene Waldformationen (zwei Brachewälder, zwei Dorfwälder und ein Naturwald) wurden die unterschiedliche Artenzusammensetzung (Diversität) und Bestandesvolumina durch Forstinventuren beschrieben. Der dem Bestandesvolumen der Brachewälder gegenübergestellte pro-Kopf Feuerholz Bedarf ergab ein jährliches Defizit von 1,81m³ in Hongphoy und 0.05m³ in Minyakshu. Der Unterschied dieses Defizits zwischen beiden Dörfern wurde in einer abweichenden Bestandesstruktur (Dominanz der $N_2$ fixierenden Baumart *Alnus nepalensis* in den Brachewäldern Minyakshus) begründet. Über den erhobenen Feuerholzbedarf wurde ein theoretischer pro-Kopf

Flächenbedarf an Brachewald errechnet, der nötig wäre um den gesamten Feuerholz Bedarf innerhalb des Wanderfeldbau Systems zu decken. Das daraus resultierende Defizit wurde mit den Feuerholzvolumina der Dorfwälder und des verbliebenen Naturwalds gegenüber gestellt. Hieraus ergibt sich die Bedeutung der Feuerholzernte und des Wanderfeldbau als Ursache für die fortschreitende Entwaldung und Forstdegradation in Nagaland.

Mit Hilfe dieser Informationen und aktuellen Angaben zum Bevölkerungswachstum werden die Ergebnisse anhand einschlägiger Literatur diskutiert und letztendlich die Nachhaltigkeit und Tragfähigkeit des Wanderfeldbau Systems in dieser Region bestimmt. Mögliche Verbesserungsstrategien um der zunehmenden Ressourcendegradation zu begegnen, werden andiskutiert.

## Chapter 1:

# Introduction

The adverse consequences of tropical deforestation and land degradation have been intensely debated for the last two decades. Remaining primary forests constitute with 1,400.7 million ha about 21.5% of the global forest cover (FAO, 2006), whereof primary moist evergreen forests of South-East Asia (about 62.9 million ha; FAO, 2006) are considered the richest and most valuable ecosystems on the earth's land surface. South-East Asia is exceptional both for hosting four of the 25 global biodiversity hotspots – Indo-Burma, Sundaland, Wallacea and the Philippines (Myers et al., 2000) and also for its very high rate of forest habitat losses (Sodhi and Brook, 2006). South-East Asia has already lost the majority of its original vegetation and unfortunately this process is continuing (Gustafsson et al., 2007). According to estimates by the United Nations Food and Agriculture Organization (FAO, 2006) about 1.5 million hectares of tropical forests were lost in South-East Asia annually from 2000 to 2005. In the four hotspots of South East Asia mentioned above, only 3% of primary vegetation remain in the Philippines, 5% in Indo-Burma, 8% in Sundaland and 15% in Wallacea (Primack and Corlett, 2005).

The loss of forest cover influences the climate and contributes to a loss of biodiversity (Stern, 2006). Further on, reduced timber supplies, siltation, flooding, and soil degradation affect the economic activity and threaten the livelihoods and cultural integrity of forest-dependent people (Kaimowitz and Angelson, 1999; Lal et al, 1998).

The causes of deforestation and forest degradation are complex. Geist and Lambin (2002) identified demographic factors as one of the five most important underlying causes - leading to agricultural expansion, wood extraction and expansion of infrastructure as most important direct causes of deforestation. While it has been recognized that shifting cultivation is one of the main culprits of tropical deforestation, in fact shifting cultivation with a long fallow cycle by itself does not cause depletion of forests (Bawa and Dayanandan, 1998) and causes relatively low damage when it takes place in secondary forests. However, a shorter fallow cycle gradually was taken on in response to the need for more arable areas for increased food and cash crop production at limited land availability. FAO/UNEP (1981) estimated that more than 200 million ha of land in closed forest regions are part of the shifting cultivation cycle, which is the equivalent of about one fifth of the tropical closed forest areas and accounts for nearly half of tropical deforestation (Angelsen, 1997). At the same time, the area under shifting cultivation increases every year by 1-2% on the global level (Amelung and Diehl, 1992) with extreme variations between regions and individual countries. Cleuren (2001) reported that shifting cultivation accounted for 70% of total deforestation in Africa, 50% in Asia, and 35% in Tropical America, respectively. While agricultural expansion is blamed as a root cause of forest and land degradation, it is often merely a reflection of farmers' needs to secure their livelihoods given declining yields on existing cropland, changes in food prices and population growth. During the past year (2007), as a consequence of higher energy and fertilizer costs, increased global food demand, the loss of arable land to biofuel crops, price speculations and droughts, the price of rice, staple crop for 2 billion people in Asia, tripled leading to widespread under-nutrition (Khor, 2008).

Nagaland in North-East India (93.20° - 95.15° E and 25.60° - 26.40° N, Figure 1) is considered to be one of the world's biodiversity hot-spots, containing the most northern evergreen wet forest (Anonymous, 2007) on hilly terrains at altitudes between 194 to 3,826 m a.s.l. Its population of about 2 Mio people lives in eight districts and consists to 89% of Naga belonging to 16 different tribes. 59% of the population depended on slash and burn agriculture, locally referred to as 'Jhum' cultivation (Statistical Handbook of Nagaland, 2003; Jacobs, 1990). Average annual rainfall in Nagaland ranges from 2,000 to 3,000 mm and is unimodally distributed from May to October (Anonymous, 2009a). In summer (March to September) mean monthly temperatures range from 16-31°C, while in winter (October to February) they vary from 4-24°C (Anonymous, 2009b).

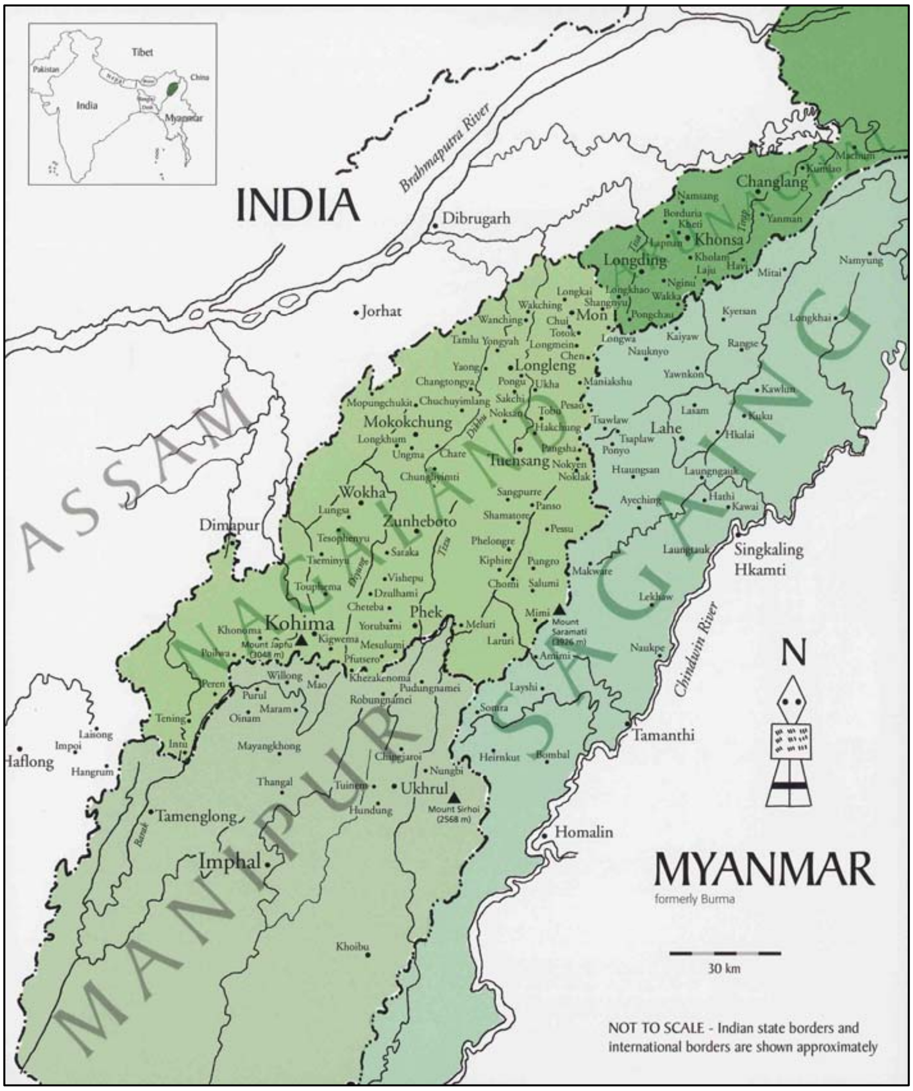



**Figure 1.** Nagaland in North-East India. Green areas indicate location of Naga tribes (van Ham and Stirn, 2003).

In 1971 the first reliable population census in Nagaland revealed a total of 516,000 people which increased to 1,988,000 in 2001, leading to a population density of 120 persons per $km^2$ (Census of India, 2001). To satisfy food needs of a growing population, in Mon District, Nagaland, fallow periods were reportedly shortened from 20 to 30 years in 1900 to today's average of 6 years (Toky and Ramakrishnan, 1981; Ranjan and Upadhyay, 1999). During the last decades most remaining forest lands were converted into shifting cultivation areas which included slopes of more than 100% (Figure 2). Most remaining forest resources are degraded; only 9% of the total area of Nagaland are classified as dense forest (State of Forest Report, 2005).

Given the rapid population increase and the continued predominance of shifting cultivation, Nagaland is particularly suited to analyse the relationship between demographic factors and the fulfilment of basic subsistence needs: cereal production and fuelwood collection, and the ensuing effects on forest and soil degradation. Based on field surveys conducted in two contrasting villages in 2004 and 2005, this study compares human demands for cereals and firewood with actual crop yields and discusses the results in the light of literature data. In this way, the carrying capacity of Jhum systems in this specific region of North-East India is determined, consequences of the typically low grain yields from shifting cultivation on food availability are analysed, and potential adaptation strategies to increasing resource degradation and scarcity are elaborated.

**Figure 2**. Shifting cultivation on steep terrain in the hills of Nagaland, Mon District.

Following this introductory chapter, chapter 2 aims at quantifying the cereal demand in the two villages, Hongphoy and Minyakshu, to analyze the gap between local farmers' food demand in cereals and the amounts harvested from slash and burn fields.

Data are based on interviews on household size, food consumption, crop yields, duration of fallow periods and on the determination of field sizes over two years. The harvested amount of cereals was converted to daily caloric intake per caput and compared within the two studied villages as well as to recent literature sources.

The relation between the average annual harvest per caput and the caloric demand allows quantifying a caloric intake shortage under consideration of the means and availability of purchasing food from outside. By those information and the current population growth figures, it is possible to reveal the situation of the rural population.

Chapter 3 describes the state of forest and wood resources within the same two villages. To this end it is differentiated between village forests, fallow forests and a natural forest stand. Forest inventories, interviews and counts of the amount of harvested wood products were carried out to compare the harvests and demands of fuelwood. The average per caput fuelwood requirement is compared to the fuelwood availability from fallow forests and used to calculate a theoretical minimum fallow area required to satisfy the fuelwood demands. Special emphasis is placed on the consequences of reduced fallow periods for the amount and dimensions of harvestable fuelwood, on the potential role of $N_2$-fixing tree species (*Alnus nepalensis*) for soil productivity during fallow periods, and on the potential of planted village forests.

Village forests and natural forests are assessed as alternative fuelwood sources with reference to stand diversity and management and compared to Jhum fallow forests, allowing an assessment of the effects of fuelwood collection and shifting cultivation as major causes of deforestation and forest degradation in Nagaland.

Finally, chapter 4 reflects on the results two main chapters and discusses the validity of the applied methods. Based on that, some general conclusions are drawn on the implications for the sustainability of the landuse system in Nagaland.

**References**

Amelung, T. and Diehl, M. (1992), 'Deforestation of Tropical Rain Forests: Economic Causes and Impact on Development'. Tübingen.

Angelsen, A. (1997), ´The poverty-environment thesis: was Brundtland wrong?'. *Forum for Development Studies* 1, 135-154.

Anonymous (2009a), 'India Information', http://www.whereincity.com/india/ nagaland/mon.php (accessed on 25/01/2009).

Anonymous, 2009b.General information, http://nagaland.nic.in/potential/tourism.htm (accessed on 25/01/2009).

Anonymous (2007), 'Biodiversity Hotspots', http://www.biodiversityhotspots.org/ Pages/default.aspx (accessed on 15/07/2008).

Bawa, K.S. and Dayanandan, S. (1998),'Global climate change and tropical forest genetic resources'. *Climatic Change*, 39(2), 473-485.

Census of India (2001), Government of India, Registrar General & Census Commissioner. New Delhi, India.

Cleuren H.M.R.H. (2001), ´Paving the road for forest destruction: key actors and driving forces of tropical deforestation in Brazil, Ecuador and Cameroon´. Leiden development studies 1. Dissertation Leiden University.

FAO (2006), 'Global Forest Resource Assessment 2005'. *FAO Forestry Paper* 147, Rome.

FAO/UNEP (1981) 'Tropical Forest Resource Assessment Project'. *FAO*, Rome.

Census of India (2001), Nagaland, District Census Handbook. Dimapur, India.

Geist, H.J., and Lambin, E.F. (2002), 'Proximate Causes and Underlying Driving Forces of Tropical Deforestation'. *Bioscience* 52(2).

Jacobs, J. (1990), 'The Nagas, Hill Peoples of Northeast India: Society, Culture and the Colonial Encounter'. London.

Gustafsson, L., Nasi, R., Dennis, R., Nghia, N.H., Sheil, D., Meijaard, E., Dykstra, D., Priyadi, H., Thu, P. (2008), 'Logging for the ark'. *CIFOR Occasional Paper* 48. Jakarta.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A.B. and Kent, J. (2000), 'Biodiversity hotspots for conservation priorities'. *Nature* 403, 853-858.

Kaimowitz, D. and Angelson, A. (1999), 'Rethinking the Causes of Deforestation'. *The World Bank Research Observer*. 14(1), 73–98.

Khor, G.L. (2008), 'Food production strategies for improving household food security amidst rising food prices'. *International Food Research Journal* 15(3), 249-257.

Lal, M., Singh, K.K., Rathore, L.S., Srinivasan, G. and Saseendran, S.A. (1998), 'Vulnerability of rice and wheat yields in NW India to future changes in climate'. *Agricultural and Forest Meteorology* 89(2), 101-114.

Primack, R.B. and Corlett, R. (2005) 'Tropical Rain Forests: An Ecological and Biogeographical Comparison'. Sommerset.

Ranjan, R. and Upadhyay, V.P. (1999), 'Ecological problems due to shifting cultivation'. *Current Science* 77(10), 1246-1250.

Sodhi, N.S. and Brook, B.W. (2006), 'Southeast Asian Biodiversity in Crisis'. *Tropical Biology Series*, Cambridge University Press, Cambridge.

State of Forest Report (2005), 'Forest Survey of India'. Ministry of Environment & Forests, Dehradun.

Statistical Handbook of Nagaland (2003). Directorate of Economics & Statistics, Government of Nagaland, Kohima, India.

Stern, N. (2006), 'The Economics of Climate Change'. Cambridge.

Toky, O.P. and Ramakrishnan, P.S. (1981), 'Cropping and yields in agricultural systems of the North-Eastern hill region of India', *Agro-Ecosystems* 7, 11-25.

Van Ham, P., Stirn, A. (2003) The hidden world of the Naga'. Prestel, London.

**Chapter 2:**

# Agricultural sustainability and food security in Nagaland (N.-E. India)

**M. Krug[a], E. Schlecht[b], A. Buerkert[a]**

[a] Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics, University of Kassel, Steinstr. 19, D-37213 Witzenhausen, Germany;
[b] Animal Husbandry in the Tropics and Subtropics, University of Kassel and Georg-August Universität Göttingen, Steinstr. 19, D-37213 Witzenhausen, Germany

## Abstract

Little is known about the agricultural productivity and rural communities' food security in Nagaland (North-East India) where high population growth leads to increasingly shorter fallow periods and a reported decline in soil productivity. This problem is particularly severe in the Mon District, where 93% of the population depends on shifting cultivation and the duration of fallows has been reduced from > 15 to six years. The present study was carried out in two villages, Hongphoy and Minyakshu, to quantify the gap between local farmers' food demand in cereals and the amounts harvested from their slash and burn fields. Data are based on comprehensive interviews on household size, food consumption, crop yields, duration of fallow periods and on the determination of field sizes over two years.

The results indicated that per caput field size available for cultivation averaged 1,800 m² in Hongphoy and 1,100 m² in Minyakshu. Per adult the daily caloric intake from harvested cereals such as rice (*Oryza sativa* L.), millet (*Pennisetum glaucum* L.) and maize (*Zea mays* L.) was in Hongphoy 9,100 kJ in 2004 and 7,300 kJ in 2005. In Minyakshu, these values were with 6,800 and 6,400 KJ even lower. On average the 2005 harvests allowed to feed an average household for nine and a half months in Hongphoy and for nine months in Minyakshu. Hence during this year in both villages one quarter of the needed cereals had to be purchased from outside, in order to fill a village level food gap of 130 t of rice in Hongphoy and of 480 t in Minyakshu. This already delicate food situation is further aggravated by an annual population growth of 6.7%.

**Keywords:** Energy demand; Jhum agriculture; Population growth; Shifting cultivation

## 1. Introduction

Situated in the North-East of India, Nagaland is one of the remotest and most secluded states of the subcontinent. After World War II, it was declared a restricted area, for which access regulations were only lifted in 1997. Since then, only very few studies on the culture and traditions of the Naga people were published and even less is known about the productivity of the local land use systems and people's food security. To close this gap of knowledge, a field study was conducted in 2004 and 2005 in the villages of Hongphoy and Minyakshu in the Mon District of Nagaland.

Nagaland is one of the world's biodiversity hot-spots, containing the most northern evergreen wet forest (Anonymous, 2008a). Its population consists to 89% of Naga belonging to 16 different tribes. The majority of the population (59%) still depends on slash and burn agriculture, locally referred to as 'Jhum' cultivation (Statistical Handbook of Nagaland, 2003). In the Mon District, 93% of the total population live of Jhum cultivation, which occupies 51% of the total area while only 3% of the land is used for wet rice fields (*Oryza sativa* L.) since the terrain is too steep for irrigation (Directorate of Agriculture, 2001). The Jhum system in Nagaland is a typical slash and burn system similar to the classical ones described by De Schlippe (1956) for Africa, Conklin (1957) for Asia and Weidelt (1968) for Latin America. In the first year of a Jhum cultivation cycle, a freshly cleared field is typically planted with upland rice (*Oryza sativa* L.), pearl millet (*Pennisetum glaucum* L.), maize (*Zea mays* L.) and with secondary crops in small quantities such as yams (*Dioscorea* spp.), cassava (*Manihot esculenta* Crantz), cucumber (*Cucumis sativus* L.), ginger (*Zingiber officinale* Roscoe), chilli pepper (*Capsicum annum* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum&Nakai), pumpkin (*Cucurbita* spp.), mustard (*Brassica juncea* (L.) Czern), sweet potato (*Ipomoea batatas* L.) and various pulses. In the second year, a new cultivation area is established at another predetermined location, while the previous year's area is maintained for the cultivation of vegetables, tuber crops and a few millet and maize plants. Within the total area of cultivation, ownership of fields is permanently marked by stones, furrows and fire resistant plants such as different bamboo species (Neped, 1999).

Reportedly as a consequence of high population growth, fallow periods in the Mon District have been shortened from 15 to 30 years in 1900 to today's average of six years (Ranjan and Upadhyay, 1999). There is little alternative to Jhum cultivation in the hills of Nagaland, since the Nagas highly value the cultivation of rice for subsistence (Jacobs, 1990). In general, food consumption is similar to that of Myanmar and Bangladesh, where 74% and 75% of the required dietary energy are supplied by rice, while cultivation of high value cash crops is hindered by a poor marketing infrastructure. Emigration to other areas is impossible, since Nagaland borders with the closed-off Myanmar and the Indian state of Assam, which is even more densely populated.

To fill the gap of knowledge about the role of Jhum cultivation for cereal-based diets of Nagaland, this study aimed at comparing the amount of harvested cereals and food purchases to the total food energy requirements of the local population. In our study quality criteria of the diet such as the concentration of protein, micro-nutrients (Fe and Zn) and vitamins were neglected since such data were too difficult to collect at the village scale. Included, however, was an assessment of the amount and sources of additional cash income of farm households to explore to what extent farmers may be able to balance insufficient harvests by rice purchases.

## 2. Materials and Methods

### 2.1. Study sites

Nagaland stretches between 93.20° - 95.15° E and 25.60° - 26.40° N and is inhabited by about 2 Mio people who live in a total area of 16,579 km², resulting in an average population density of 120 people km$^{-2}$ (Statistical Handbook of Nagaland, 2003). This study took place in Nagaland's Mon District where 93% of the population depends on shifting cultivation, which is the highest rate among all eight districts of Nagaland (Statistical Handbook, 2003). Annual rainfall averages 2,000-3,000 mm, concentrated in the months of May to October (Anonymous, 2008b). In summer (March to September) mean monthly temperatures range from 16-31°C, while in winter (October to February) they vary from 4-24°C (Anonymous, 2008c). The district capital Mon lies at about 900m a.s.l. Within the Mon District, the two villages of Hongphoy and Minyakshu were chosen to compare different socio-economic scenarios. Hongphoy is situated at 8 km from Mon, whose markets can be reached within 3 h on foot, while Minyakshu is situated in the steep upper Konyak hills and during the dry season can be reached by a 6 h bus trip. Here cultivated Jhum fields are located on slopes sometimes > 150%. During the rainy season, Minyakshu is cut off from the district's capital.

### 2.2. Measurement of field size

In each of the two villages the area of 60 fields was determined in April 2004. Only recently slashed and burned fields were taken into account; they belonged to randomly chosen families whereby fields on slopes > 150% were excluded. Traverses were measured along the marked field borders with the help of a compass and a Suunto altimeter, subsequently field size was calculated according to the following formula of Gauß:

$$2A = \Sigma x_i * (y_{i+1} - y_{i-1})$$

where the field corners are identified with the coordinates $x_i$ and $y_i$ in counter-clockwise direction for calculating the fieldsize A. To calculate the field size per head and annum, the second year's Jhum area and the size of wet rice fields were added to the first year's Jhum area.

### 2.3. Semi-structured interviews

In spring 2004, 60 semi-structured interviews were conducted in Hongphoy in those of the village's 164 households whose field sizes had been measured previously. Similarly, the interviews in Minyakshu were conducted with those families whose field sizes were known.

However, to cover at least one third of the 581 families of this village, an additional 164 interviews were conducted with randomly selected households. During the interviews the number of household members and the age structure of children were noted. Further questions addressed quantities of rice, millet and maize that were harvested in August and September 2003. Also questioned was whether the harvested yields were deemed to be sufficient for the entire year. Other questions tackled the cropping sequence of the Jhum fields, the total field number belonging to the household, and whether the household additionally owned a wet rice field. The extent and source of cash income from salaries, earnings in the informal sector or remittances from relatives were also noted.

In spring 2005, the same 60 families in Hongphoy and Minyakshu, whose fields had been measured previously, were interviewed again. These interviews comprised the same questions as in 2004 and were mainly conducted to record the quantities of rice, millet and maize harvested in August and September of the previous year on the measured Jhum fields and to obtain a second data set on household sizes, rice purchases and off-farm income. These data were marked with 2004 and 2005 in our study since interviews were conducted in February and March of these years although yield data refer to the harvests of autumn 2003 and 2004.

### 2.4. Analysis of interview data

At both locations data obtained from the 60 families whose fields were measured were summarized as means or percentages unless reported otherwise. All quantities of rice, millet and maize refer to ground amounts in kg, whereby the conversion factors of raw cereals to milled cereals used were 0.7 for rice, 0.56 for maize (Juliano, 1993) and 0.7 for millet (pers. communication T. Streckel, Streckel & Schrader KG, Nahrungsmittelmaschinen, Hamburg, Germany.). All monetary values were converted into Euro based on an exchange rate of 52.2 Indian Rupees (INR) for 1 Euro.

To estimate a household's caloric intake from cereals, harvested and purchased amounts of milled rice, millet and maize were converted to energetic values in joule. According to Juliano (1993), 100 g of milled rice contain 375 kcal (1570 Joule), of millet 394 kcal (1650 Joule) and of maize 397 kcal (1660 Joule). Caloric intake requirements of children and adolescents (0 to 17 years) were assumed to be 72.5% of those of adults. This figure was calculated based on energy intake data of specific age groups in India (Gopalan et al., 1981).

**2.5 Current population density and prediction of population growth**

The population density in the villages Hongphoy and Minyakshu village (head per $km^2$) was calculated on the basis of measured field size per person whereby it should be noted that only 51% of the total land area are subject to Jhum cultivation (Statistical Handbook of Nagaland, 2003). In 2005, a census was carried out in Hongphoy to obtain data on family structures, the male and female gender ratio and birth rate. These data were used to calculate the total fertility rate (TFR) which allowed predictions of population growth using the software Spectrum (USAID, 2007).

## 3. Results and discussion

### 3.1. Data sets, family structures and field sizes

Interview results showed major differences between the two studied villages. The most important contrast was the fact that in Hongphoy the main cereal cultivated is upland rice, whereas in the much larger Minyakshu, millet and maize are the dominant Jhum crops. In 2004, household sizes were slightly larger in Minyakshu with 7.6 family members compared to 7.3 family members in Hongphoy, a trend which was confirmed in 2005 (Table 1).

**Table 1.** Structure of the interviewed households in the villages of Hongphoy and Minyakshu, Nagaland, N.-E. India in 2004 and 2005.

| **Variable** | **Hongphoy** | | **Minyakshu** | |
|---|---|---|---|---|
| | **2004** | **2005** | **2004** | **2005** |
| Total population (n) | 1,239 | 1,257 | 4,870 | 5,253 |
| Number of households | 164 | 187 | 581 | 639 |
| Number of interviewed households | 60 | 60 | 60 | 60 |
| Number of recorded inhabitants | 439 | 455 | 458 | 494 |
| Children (%) | 51 | 57 | 47 | 47 |
| Average size of household (n) | 7.3 ±2.8 | 7.6 ±2.9 | 7.6 ±4.1 | 8.2 ±4.0 |
| Number of children per household | 3.7 ±1.7 | 4.4 ±2.0 | 3.6 ±2.2 | 3.8 ±2.8 |
| Number of measured Jhum fields | 60 | 0 | 60 | 0 |

Another important difference between both villages was the available field size of first year Jhum fields per person. In Minyakshu, average size of those fields was 55% of that in Hongphoy and in addition these fields had to be shared by a larger number of household members (Table 2).

**Table 2.** Size of first year Jhum fields in the villages of Hongphoy and Minyakshu, Nagaland, N.-E. India in 2004. Data show means ± one standard error.

| **Variable** | **Hongphoy** | **Minyakshu** |
|---|---|---|
| Measured Jhum fields (n) | 60 | 60 |
| Average size of new Jhum field per household ($m^2$) | 7,604 ±2,781 | 4,189 ±2,224 |
| Average size of new Jhum field per caput ($m^2$) | 1,039 ± (439) | 549 ± (458) |

### 3.2. Management of Jhum fields

Within the cultivated area, individual fields were permanently marked as they belonged to a particular family. The decision upon which area is dedicated to Jhum cultivation in a respective year is made by the village elders and not the individual household. However, traditionally, each household cultivates one Jhum field for two years before it falls fallow, whereby the length of the fallow period has been reduced from 15 - 30 years in 1900 to today's 7 years in Hongphoy and 5 years in Minyakshu (Ranjan and Upadhyay, 1999).

In Minyakshu, field size was much smaller than in Hongphoy, forcing families to cultivate more than just one new Jhum field per year. Furthermore in Minyakshu the availability of Jhum fields per household was more skewed than in Hongphoy (Figure 1). Households partly compensated an insufficient number of fields by rice purchases and often rented fields from other households or even neighbouring villages. In Minyakshu, families tended to work within other fields in exchange for monetary payments or compensation in cereals.

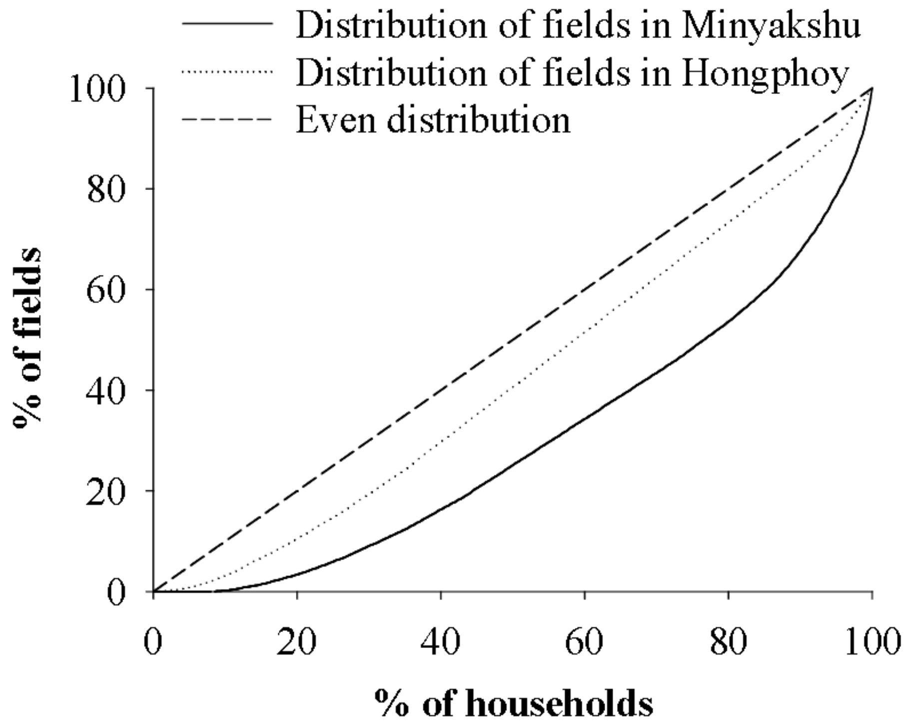



**Figure 1.** Distribution of fields among households in the villages of Hongphoy and Minyakshu, Nagaland, N.-E. India in 2004.

In 2004, due to labour shortages, 28% of the households in Hongphoy did not cultivate their Jhum field in the second year; hence these fields might remain fallow for 8 years. In Minyakshu, 17% of the households left their field fallow, reportedly mainly due to a depletion of soil productivity. In 2005, in both villages fewer families abandoned their fields in the second Jhum year than in 2004. In general, in Minyakshu more exceptions from the typical Jhum rule ‘each year one first year Jhum plus one second year Jhum’ were observed and management of fields was more irregular. In this village, the effects of land shortage on household food self sufficiency were mitigated by the fact that at least every second household owned an additional wet rice field (Table 3).

While an average villager in Hongphoy was growing crops on 1,800 m²; in Minyakshu he had only 1,100 m² (Table 4). Additionally, a person in Hongphoy had 14 m² and in Minyakshu 78 m² of wet rice.

**Table 3.** Ownership and management of Jhum fields (n = 60) in the villages of Hongphoy and Minyakshu, Nagaland, N.-E. India in 2004 and 2005. Data show means ± one standard error.

| Variable | Hongphoy | | Minyakshu | |
|---|---|---|---|---|
| | **2004** | **2005** | **2004** | **2005** |
| Length of the Jhum cycle (years) | 9 | 9 | 7 | 7 |
| Own Jhum fields per household (n) | 8.3 ±2.7 | 8.6 ±2.9 | 8.1 ±4.9 | 8.0 ±5.0 |
| Households that do not own any field (%) | 0 | 0 | 0 ( 8*) | 0 |
| Households which cultivate more than one new Jhum field (%) | 0 | 2 | 0 (21*) | 35 |
| New Jhum fields per household (n) | 1.0 | 1.0 | 1.0 | 1.4 |
| Households which do not cultivate a new Jhum field (%) | 0 | 0 | 0 (12*) | 0 |
| Households which abandoned their old Jhum field (%) | 28 | 25 | 17 | 5 |
| Wet rice fields per household (n) | 0.03 | 0.03 | 0.47 | 0.48 |

* Figures in brackets refer to the dataset of 225 families

**Table 4.** Cultivated area per caput and annum and population density in the villages of Hongphoy and Minyakshu, Nagaland, N.-E. India in 2004.

| Variable | Hongphoy | Minyakshu |
|---|---|---|
| Average size of new Jhum field per caput ($m^2$) | 1,039 | 549 |
| Households which abandon their old Jhum field (%) | 25 | 5 |
| Calculated size of old Jhum field per caput ($m^2$) | 779 | 522 |
| Cultivated Jhum area per caput and annum ($m^2$) | 1,818 | 1,071 |
| Average size of wet-rice field per caput ($m^2$) | 14 | 78 |
| Number of own Jhum fields per household | 8.2 | 8.1 |
| Total area one person has at its disposal for Jhum ($m^2$) | 8,520 | 4,447 |
| Land used for Jhum cultivation (%) | 54 | 54 |
| Population density in area around villages (person $km^{-2}$) | 63 | 121 |

### 3.3 Harvested cereals per hectare

Upland rice yields per hectare were 3.5-fold higher in Hongphoy than in Minyakshu (Table 5). This compares to upland rice yields of 1,600 – 3,000 kg $ha^{-1}$ in Northern Thailand (Chapman, 1973) and yields of 495 – 1,858 kg $ha^{-1}$ on non fertilized plots in Sarawak (Bech Bruun et al., 2005). The most important crop in Hongphoy was rice, while millet was not grown at all and maize only to a minor extent. Only a small proportion of the rice was wet rice but there is potential for the establishment of additional wet rice fields. The situation is different in Minyakshu where the main crops on Jhum fields were millet and maize. Only little upland rice was grown, since soils were reportedly too poor for rice. The low quantities of harvested Jhum rice were substituted by wet rice.

Taking yields of millet and maize into account, in both villages average total cereal yields per hectare from first year fields were about 1,200 kg $ha^{-1}$ (Table 5). In 2005 only 17% of total cereals came from second year Jhum fields in Hongphoy and 23% in Minyakshu. Those fields played only a minor role for the cultivation of cereals but were important for planting vegetables and fruits.

**Table 5.** Rice, millet and maize yields per hectare on Jhum fields of the first year (number of fields = 60) in Hongphoy and Minyakshu, Nagaland, N.-E. India in 2005. Values beyond 0.5 x standard deviation were excluded. Data in brackets indicate the number of households interviewed.

| **Variable** | **Hongphoy, 2005** | **Minyakshu, 2005** |
|---|---|---|
| Harvested rice per hectare (kg $ha^{-1}$) | 895 ±127 (30) | 259 ± 91 (18) |
| Harvested millet per hectare (kg $ha^{-1}$) | 0 | 605 ±215 (32) |
| Harvested maize per hectare (kg $ha^{-1}$) | 222 ± 69 (23) | 389 ± 87 (21) |
| Total of rice, millet and maize (kg $ha^{-1}$) | 1183 ±166 (31) | 1,216 ± 432 (30) |

### 3.4 Consumed quantities of cereals and energy requirements per caput

While upland rice dominated cereal consumption in Hongphoy, the diet was more diverse in Minyakshu. Here upland rice was complemented by millet, maize and rice from paddy fields although farmers stated that their most favourite cereal was rice from Jhum fields (Figure 2).

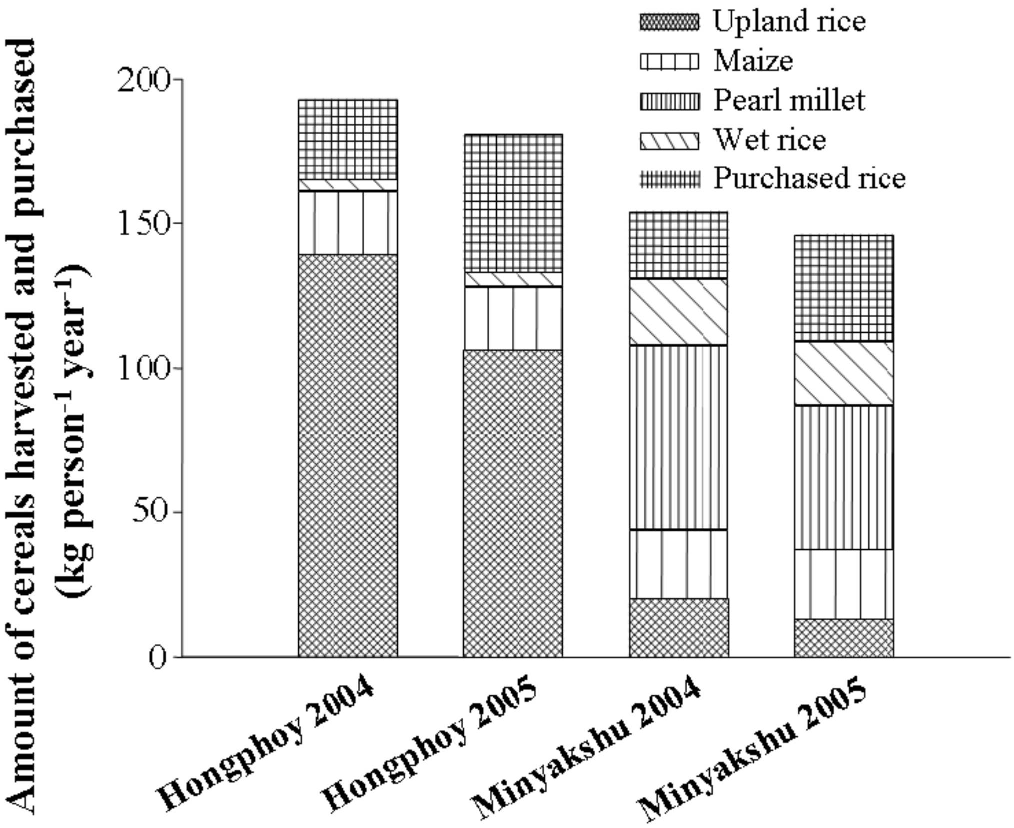



**Figure 2.** Sources of harvested and purchased cereals per person and year in the villages of Hongphoy and Minyakshu, Nagaland, N.-E. India in 2004 and 2005.

Quantities of maize harvested in Hongphoy in 2004 were not available and had to be estimated from the 2005 figures. Harvests of rice in Hongphoy and of rice, millet and maize in Minyakshu were lower in 2005 than in the previous year and subsequently more rice had to be purchased in 2005.

The energy calculations revealed that for Hongphoy in 2004 harvested cereals yielded on average 9,100 kJ per caput and day ($c^{-1}$ $d^{-1}$) to which an additional 1,400 kJ $c^{-1}$ $d^{-1}$ came from purchased rice (Figure 3). In Minyakshu in 2004 only 6,800 kJ $c^{-1}$ $d^{-1}$ were derived from harvested cereals and 1,300 kJ $c^{-1}$ $d^{-1}$ were from purchased rice. In 2005 these values were even lower in both villages; in Minyakshu 6,400 kJ $c^{-1}$ $d^{-1}$ were supplied by cereal harvests and 2,000 kJ $c^{-1}$ $d^{-1}$ from rice purchases. These data compare to FAO daily minimum dietary energy requirement of 10,000 kJ $d^{-1}$ for an adult in North-East India (Anonymous, 2008d) and to even higher values recommended by Gopalan et al. (1985). The latter authors reported daily energy expenditures of an adult male in India to be 10,000 kJ for sedentary work, 11,700 kJ for moderate work and

16,300 kJ for heavy work. Given the time spent on land clearing, planting, weeding and harvest, the work load of a Jhum farmer may be classified as moderate to heavy. The energy intake from cereals is therefore considerably lower than the threshold associated with the field work in Jhum agriculture.

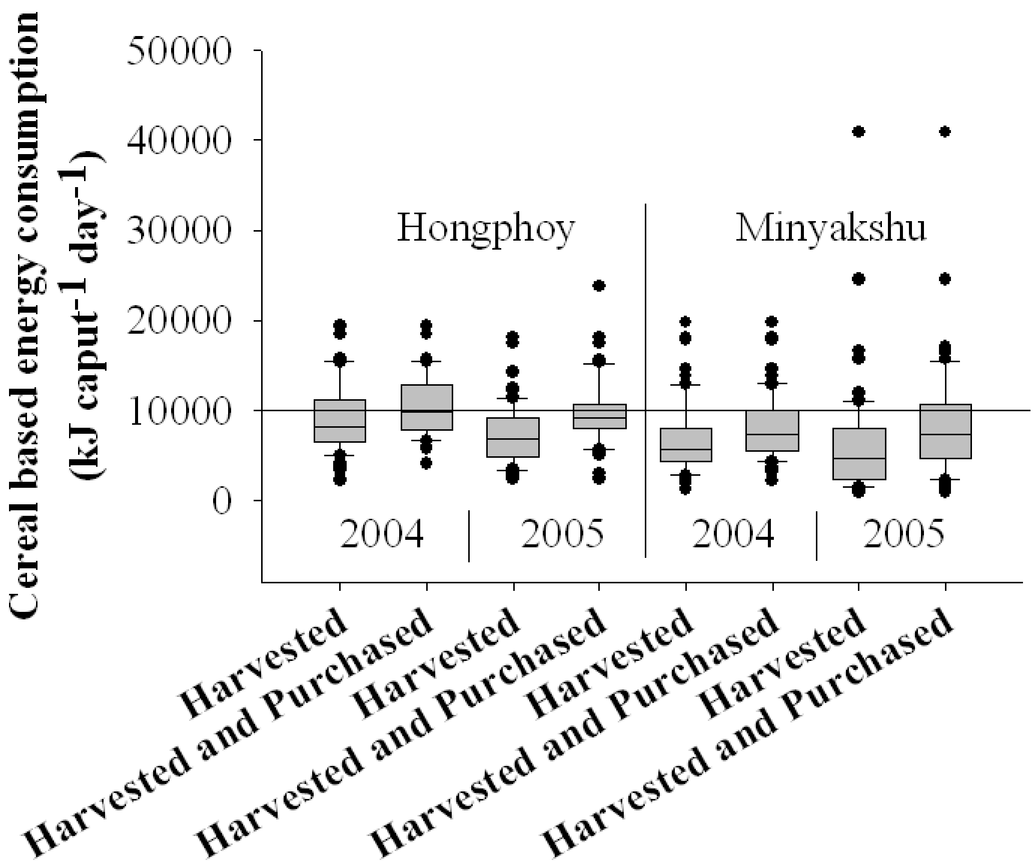



**Figure 3.** Average daily energy consumption by adults of a cereal based diet derived from imported and harvested amounts of rice, millet and maize in the villages of Hongphoy and Minyakshu, Nagaland, N.-E. India in 2004 and 2005.

Especially in Minyakshu the existing energy gap is unlikely to be closed by the consumption of meat, oil, sugar or other foodstuffs that are rarely available, and meeting minimum energy demands will thus rely on the availability of the secondary crops of sweet potato or cassava.

### 3.5 Quantities of purchased rice and additional income

Both villages strongly depended on rice supplies from Assam (Table 6). While in 2004 in Hongphoy and Minyakshu 200 and 170 kg per household were bought, respectively, in 2005 purchased quantities doubled due to low harvests, and reached 47 kg per caput in Minyakshu, equivalent to total rice imports of < 250 t per village.

**Table 6.** Additional food supply derived from purchased rice in the villages of Hongphoy and Minyakshu, Nagaland, N.-E. India in 2004 and 2005. Data in brackets indicate the number of households interviewed.

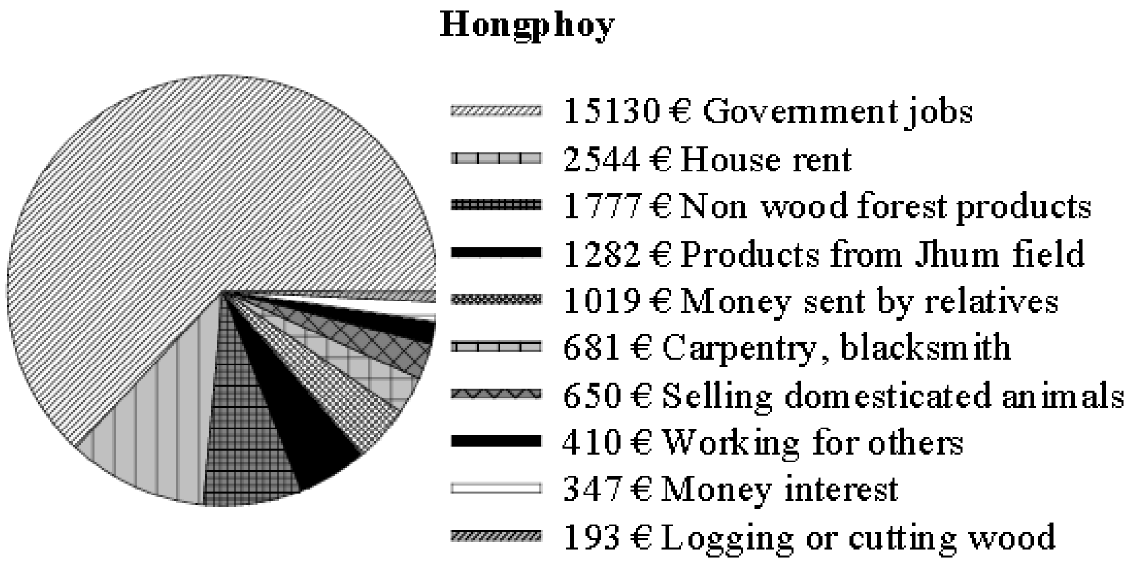
| **Criterion** | **Hongphoy** | | **Minyakshu** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| Purchased Assam rice per data set N= households (kg) | 12,350 (60) | 21,638 (54) | 10,395 (60) | 18,443 (46) |
| Purchased Assam rice per household (kg) | 206 ±279 | 401 ±379 | 173 ±236 | 401 ±502 |
| Purchased Assam rice per caput and year (kg) | 28 | 53 | 23 | 47 |
| Purchased Assam rice per caput and year (€) | 7 | 14 | 6 | 12 |
| Purchased Assam rice per village (tons) | 34 | 67 | 112 | 247 |

The heavy dependence of household food security on purchased rice makes Jhum farm households with an annual per capita cash income of only 40 - 50 € particularly vulnerable to rises in food prices (Table 7).

**Table 7.** Cash income in Hongphoy and Minyakshu, Nagaland, N.-E. India (2004 and 2005). Data in brackets indicate the number of households interviewed.

| **Criterion** | **Hongphoy** | | **Minyakshu** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| Additional income per household per year (€) | 370 ±530 (60) | 350 ±430 (60) | 300 ±480 (213) | - |
| Additional income per head (€) | 50 | 45 | 40 | - |
| Quantity of rice equivalent to the additional income (kg) | 200 | 180 | 150 | - |

In 2004, 63% of off-farm income in Hongphoy were based on government salaries as village head, member in the village court, village board, or as a school or kindergarden teacher, church administrator or pensioner. In Minyakshu 33% of off-farm income was governmental (Fig. 4). Some villagers in Hongphoy owned houses in Mon that were rented out and some also took advantage of the proximity to the district capital by selling non-timber forest products, fuelwood or products from Jhum fields on Mon's larger markets. Many inhabitants of Minyakshu depended on trade within the village, mainly with animals, but also on the sale of locally made knifes (Jacobs, 1990).



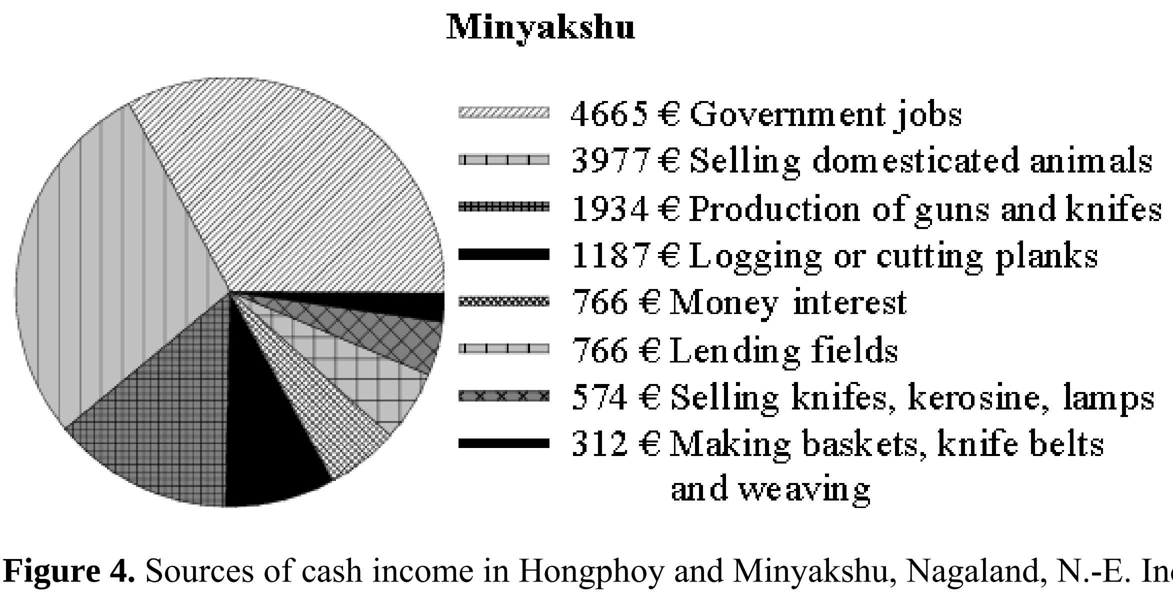




**Figure 4.** Sources of cash income in Hongphoy and Minyakshu, Nagaland, N.-E. India (2004).

### 3.6 Population growth

From 1971 – 1981, annual population growth in Nagaland was 5.0%, from 1981-1991 it was 5.6%, and from 1991 - 2001 it was 6.5% compared to an average 2.1% annual growth rate in the whole of India (Statistical Hand Book of Nagaland, 2003; Department of Planning and Coordination, 2004). Hence population density in Nagaland increased from 47 head $km^{-2}$ in 1981 to 73 head $km^{-2}$ in 1991 and to 120 head $km^{-2}$ in 2001.

For the years after 2001, Nanda and Haub (2007) calculated two scenarios of population growth for the whole of Nagaland (Figure 5). Both departed from a TFR of 3.2 for the years 2001 to 2006 but differed in that the TFR to be reached in 2021 was 2.1 for scenario A and 1.9 for scenario B.

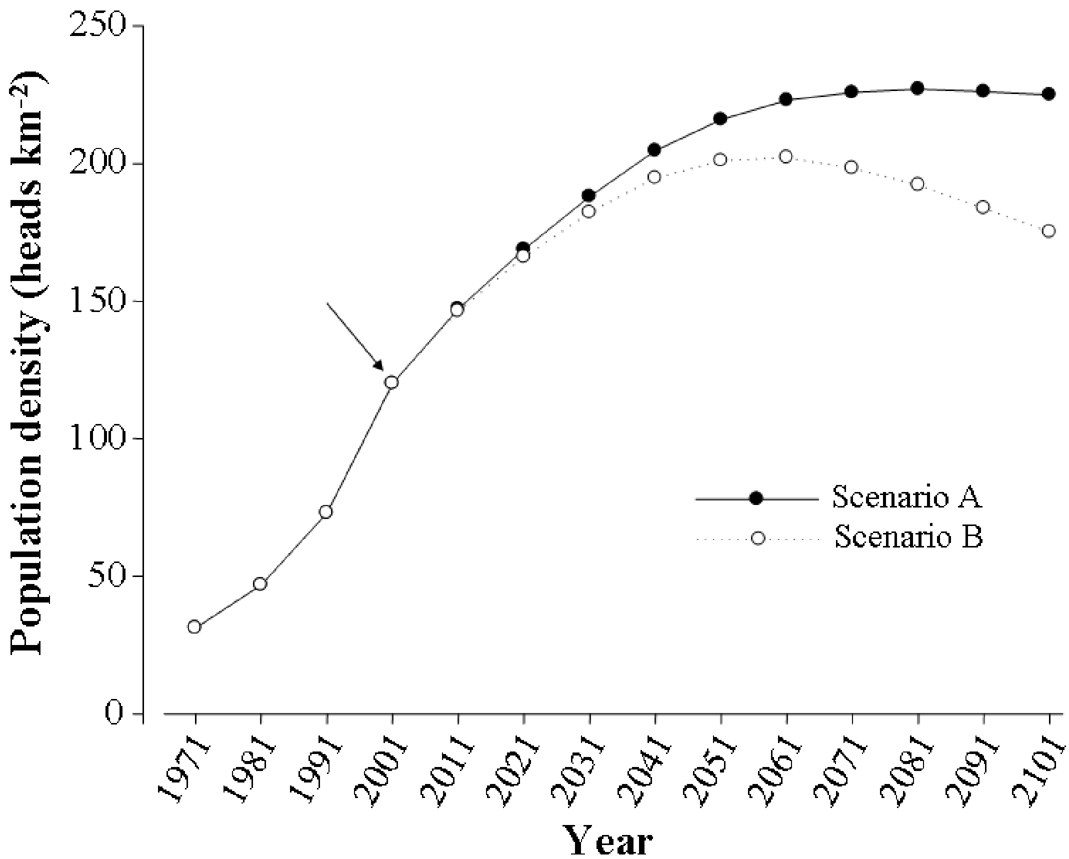



**Figure 5.** Past and predicted population growth in Nagaland, N.-E. India, as calculated by Nanda and Haub (2007). Both scenarios differ in the target totally fertility rate (TFR) reached in 2021. Scenario A assumes that the final TFR value will reach of 2.1, whereas scenario B assumes a TFR of 1.9. The arrow indicates the year when recorded data merge with the most likely assumption.

Both scenarios seem to be rather conservative compared to census data of the Government of Nagaland which indicated for 1998 an average TFR of 3.77 and a value of even 4.81 for low income households. Our own data recorded in April 2004 and March 2005 even revealed a TFR of 5.7, which was however, counteracted by high child mortality.

The predictions using the Spectrum software (Figure 6; USAID, 2007) did not take into account (i) emigration into larger cities as those movements are difficult to predict, and (ii) any likely decline in the TFR until 2015 as it was assumed by Nanda and Haub (2007). Furthermore, the model uses 'Model Life Tables' that are based on UN data for South Asia.

These tables do not take into account the high infant mortality rates typically found in Nagaland. According to government figures, infant mortality rate (IMR) was 42.2 per 1,000 births and under-five year mortality rate 63.8 per 1,000 births for the whole of Nagaland (Nagaland, State Human Development Report, 2004).

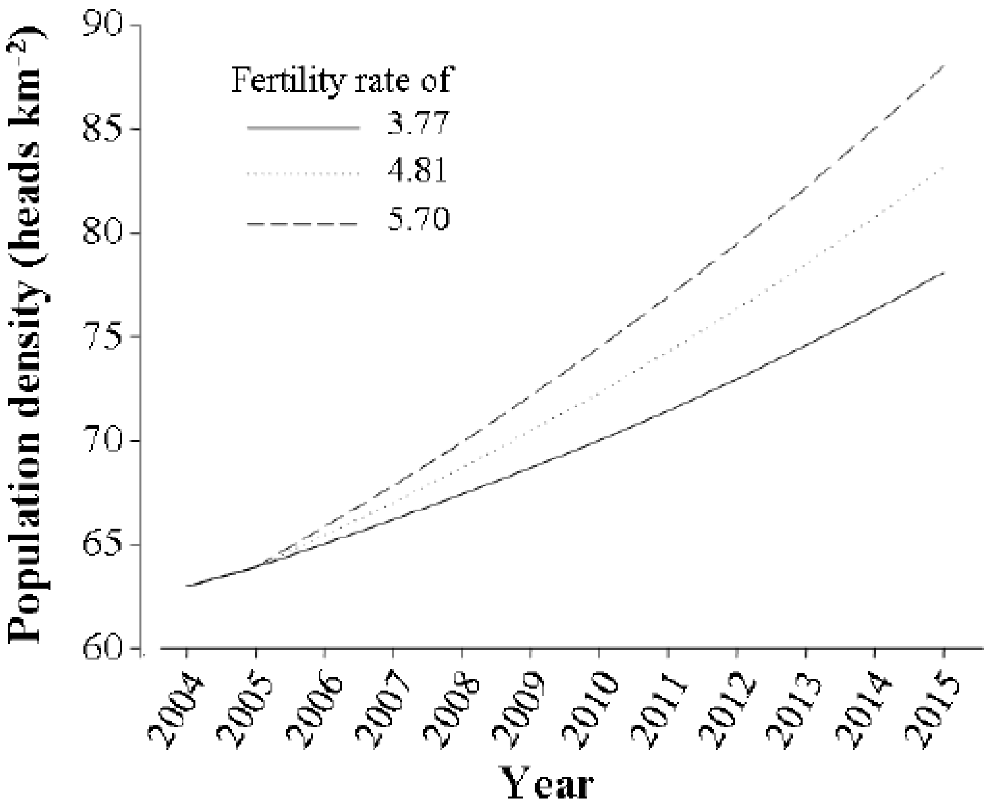



**Figure 6.** Population predictions for different fertility rates (TFR) in Hongphoy, Nagaland, N.-E. India.

However, our data showed that in Hongphoy under-five year mortality rate was much higher, namely 175 deaths per 1,000 births, despite a significant decline during the last 60 years (Figure 7). These differences indicate the doubtful quality of the official statistics on population growth in Nagaland.

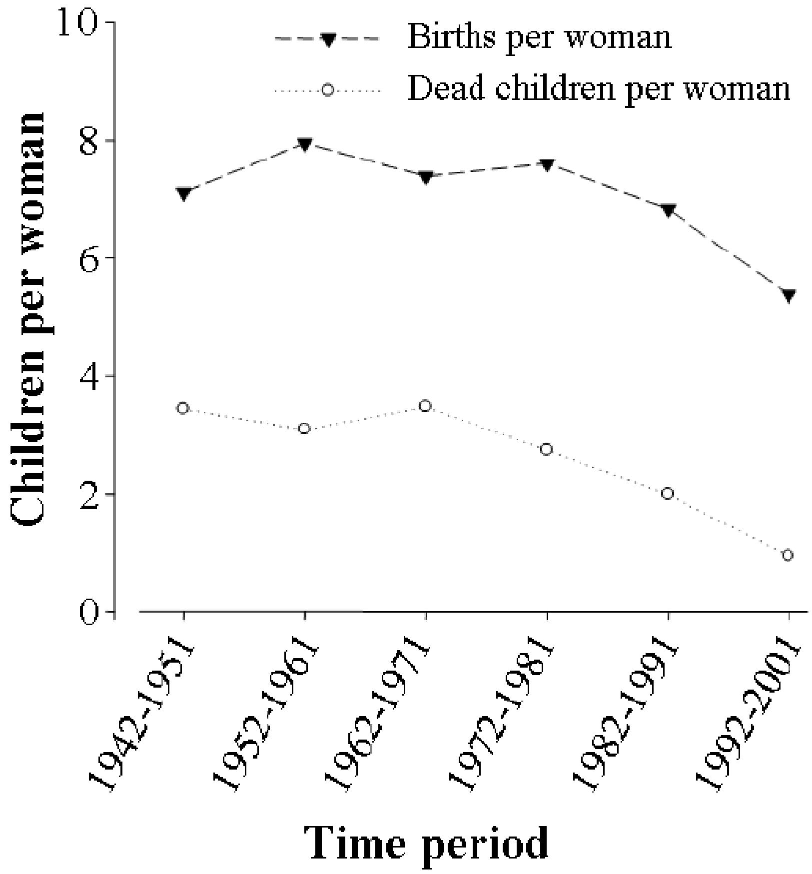



**Figure 7.** Birth rate and under-five year child mortality in Hongphoy per woman and per 1,000 births, Nagaland, N.-E. India.

Assuming that the population in Hongphoy grows with a TFR of 3.77 (lowest scenario in Figure 6) and no out-migration occurs, population density would increase from 64 persons $km^{-2}$ in 2005 to 78 persons $km^{-2}$ in 2015. At the same time this would lead to a decline in the amount of annually harvested cereals from 135 to 109 kg $person^{-1}$, which will most likely have to be compensated by increased amounts of purchased grain.

## 4. Conclusions

The presented data of yield levels and energy intake show the severe constraints to food security in the two Nagaland villages of Hongphoy and Minyakshu, whose agricultural carrying capacity at the current level of land productivity is reached if not already exceeded. The main cause of this development is the extraordinary high rate of population growth resulting from traditionally high birth rates combined with a decrease in infant mortality.

Unless land productivity can be substantially increased through the targeted use of soil amendments leading to higher yields, the food demand of Nagaland's rapidly growing population will increasingly depend on purchased rice, requiring a substantial rise in households' off-farm income or increased out-migration.

## Acknowledgements

We are indebted to the farmers of Hongphoy and Minyakshu who readily took part in interviews and field surveys. This work wouldn't have been possible without the support of Mr. Shing Wang Wangsha, Prince of Mon and Mr. Vengota Nakro and Mr. Kevin Zehoul, Neped project, Nagaland. We are also grateful for valuable discussions with Mr. Carl Haub, Population Reference Bureau, Washington, DC, USA.

## References


Anonymous (2008a). Biodiversity Hotspots, http://www.biodiversityhotspots.org/Pages/default.aspx (accessed on 15/07/2008).

Anonymous (2008b). India Information, http://www.whereincity.com/india/nagaland/mon.php (accessed on 15/07/2008).

Anonymous (2008c).General information http://nagaland.nic.in/potential/tourism.htm, (accessed on 15/07/2008).

Anonymous (2008d). Food and Agriculture Organisation of the United Nations, FAOSTAT, http://faostat.fao.org/ (accessed on 15/07/2008).

Bech Bruun, T., Mertz, O., Elberling, B. (2005). 'Linking yields of upland rice in shifting cultivation to fallow length and soil properties'. Ag*riculture, Ecosystems and Environment* 113, 139–149.

Chapman, E.C. (1973). 'Villagers as clients. A study of land development in Northern Thailand'. In: Ho, R., Chapman, E.C. (Eds.). 'Studies of Contemporary Thailand'. Research School of Pacific Studies. Department of Human Geography Publication HG/8. Australian National University, Canberra, Australia.

Conklin, H.C. (1957). 'Hanunóo Agriculture'. Vol. II of FAO series on shifting cultivation: 'A report on an integral system of shifting cultivation in the Philippines'. FAO, Rome, Italy.

De Schlippe, P.(1956). 'Shifting cultivation in Africa: the Zande system of agriculture'. Routledge and Kegan Paul, London, England.

Directorate of Agriculture (2001). 'Report on the Agricultural Census of Nagaland'. Government of Nagaland, Kohima, India. 355 p.

Gopalan, C., Ramasastri, B.V., Balasubramanian, S.C. (1985). 'Nutritive Value of Indian Foods'. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, India, 204 p.

Jacobs, J. (1990). 'The Nagas: Hill Peoples of Northeast India; society, culture and the colonial encounter'. Thames Hudson, 1990. 359 p.

Juliano, B.O. (1993). 'Rice in human nutrition'. *FAO Food and Nutrition Series* 26. Rome, Italy, 162 p.

Nagaland, State Human Development Report (2004). Department of Planning & Coordination, Government of Nagaland, 278 p.

Neped, Environmental Protection and Economic Development (1999). 'Building upon Traditional Agriculture in Nagaland, India'. International Institute of Rural Reconstruction, Bangalore, India. 235 p.

Nanda, A.R., Haub, C. (2007). 'The Future population of India. A long-range demographic view'. Population Foundation of India and the Population Reference Bureau. Ajanta Offset & Packagings Ltd., Delhi, India. 15 p.

Ranjan, R., Upadhyay, V.P. (1999). 'Ecological problems due to shifting cultivation'. *Current Science* 77(10), 1246-1250.

Statistical Handbook of Nagaland (2003). Directorate of Economics & Statistics, Government of Nagaland, Kohima, India. 360 p.

USAID (2007). Spectrum policy modelling system, version 3.15, Beta 5. USAID/Health Policy Initiative, Washington, DC, USA.

Weidelt, H.-J.(1968). 'Der Brandhackbau in Brasilien und seine Auswirkungen auf die Waldvegetation'. Dissertation zur Erlangung des Doktorgrades der Forstlichen Fakultät der Georg-August Universität Göttingen, Germany.

## Chapter 3:

# Fuelwood harvests within a system of shifting cultivation in Nagaland and its implications for forest degradation (N.-E. India)

**M. Krug[a], E. Schlecht[b], A. Buerkert[a]**

[a] Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics, University of Kassel, Steinstr. 19, D-37213 Witzenhausen, Germany;
[b] Animal Husbandry in the Tropics and Subtropics, University of Kassel and Georg-August-Universität Göttingen, Steinstr. 19, D-37213 Witzenhausen, Germany

**Abstract**

Given scarcity of information about the current state of forest resources in Nagaland, North-East India, this study quantifies fuelwood demand and availability in two villages within a traditional shifting cultivation system (Jhum). A survey revealed that average fuelwood demand was 2.7 and 2.4 $m^3$ per year and caput in Hongphoy and Minyakshu, respectively. Of those consumed amounts 1.81 and 0.05 $m^3$ originated from other forest resources than the actual Jhum fields. To avoid the ongoing forest degradation, villagers should satisfy fuelwood needs solely from Jhum fields leading to a theoretical per caput requirement of 3,164 m² fallow forest in Hongphoy and of 560 m² fallow forest in Minyakshu. This is opposed to the actual available area of 1,039 m² in Hongphoy and 549 m² in Minyakshu. The determined fuelwood gaps can be understood as an effect of population growth and shortened fallow periods. The study also indicated that *Alnus nepalensis*, a nitrogen-fixing tree may lead to increases in forest fuelwood productivity.

The study of five forest stands (two Jhum fallow forests, two village forests and one natural forest) revealed large differences in their species composition (stand diversity) and fuelwood productivity. It also indicated that fuelwood collection and shifting cultivation are major causes of deforestation and forest degradation in Nagaland.

**Keywords:** *Alnus nepalensis,* fallow regrowth, fuelwood, Jhum agriculture, population growth

## 1. Introduction

Much of the forests of North-East India have been cleared during the last century. Nevertheless, 56% of the area is still classified as forest land, and even 83% are under forest cover. But this forest cover also includes wasteland, scrubland and heavily degraded sites with a Crown Density Index (CDI) of less than 40%, only 9% of the land is still covered with dense forest of a CDI > 70% (State of Forest Report, 2005). Those remaining forests were identified as one of the world's biodiversity hot-spots (Anonymous, 2009d) and are representing the most northern evergreen wet forests globally. Ramakrishnan and Kushwaha (2001) state that local forest losses are mainly due to timber extraction for export combined with shifting cultivation, but Bhatt and Sachan (2004) hold primarily shifting cultivation coupled with excessive deforestation for fuelwood responsible for forest losses and land degradation. Already 26% of the total land area of North-East India is classified as wasteland area (Wastelands Atlas of India, 2005).

Shifting cultivation has ceased to be sustainable in the region due to rapid population growth (Krug et al., unpublished). Fallow periods have been shortened from 20 to 30 years in 1900 to today's average of six years (Toky and Ramakrishnan, 1981; Ranjan and Upadhyay, 1999) and cereal demands cannot be met anymore due to low soil productivity and a decrease in available per caput area (Dhrupad Choudhury and Sundriyal, 2003; Krug et al., unpublished). Reduced per caput area and shortened fallow periods also lead to a shortage in fuelwood since demands cannot be satisfied anymore from small, four or five year old fallow fields. Villagers in North-East India heavily depend on fuelwood for cooking and space heating (Bhatt and Sachan, 2003) and women are forced to trek 10- 15 km outside the village to collect fuelwood which accelerates forest degradation (Ramakrishnan, 1992). Many studies deal with fuelwood consumption in the Himalayan region (Maikhuri, R.K., 1994; Maikhuri and Gangwar, 1991; Maikhuri, 1990). Bhatt and Sachan (2004) contrast the amounts of needed fuelwood to available resources on a state wide basis for Meghalaya, but information on the impact of fuelwood demands on forest resources is scarce. Besides quantitative changes, little is known on qualitative forest changes as evidenced by changes in species composition or species losses in North-East India and the Himalayan region.

This study aimed at comparing the structure and species richness of fallow forests, village forests and a natural forest to indicate the qualitative extend of forest degradation. It also aimed at quantifying apparent fuelwood gaps by comparing growing stock with per caput needs.

## 2. Materials and Methods

### 2.1. Study sites

The study was conducted in 2005 in the villages of Hongphoy and Minyakshu in the Mon District of Nagaland, one of seven states of North-East India. Nagaland stretches between 93.20° - 95.15° E and 25.60° - 26.40° N and is inhabited by about 2 Mio people organized in 16 tribes living in eight districts. Annual rainfall averages 2,000-3,000 mm and is unimodally distributed from May to October (Anonymous, 2009a). In summer (March to September) mean monthly temperatures range from 16-31°C, while in winter (October to February) they vary from 4-24°C (Anonymous, 2009b).

The Mon District was chosen for this study since the majority of its population depends on shifting cultivation, and forest losses and land degradation have reduced the area covered with dense forest to only 11 km² (Table 1).

**Table 1.** Characteristics of forest cover and population density in North-East India, Nagaland and Mon District (State of Forest Report, 2005; Census of India, 2001).

| 2005 | N.-E. India | Nagaland | Mon District |
|---|---|---|---|
| Total geographical area (km²) | 183,741 | 16,579 | 1,786 |
| Forest cover (%) | 79.0 | 83.0 | 74.0 |
| Change compared to 2003 (%) | -1.0 | -1.8 | -5.3 |
| Very dense forest (CDI > 70%) (%) | 9.0 | 1.4 | 0.6 |
| Population density (heads/km²) | 68 | 120 | 145 |
| Rural population (%) | 79.0 | 83.0 | 93.0 |

Hongphoy comprises 1,257 villagers and is situated about 45 minutes by car or a three hours walk from the district capital Mon, while the larger village of Minyakshu with 5,253 villagers is situated in the more remote upper Konyak hills, about eight six by car from Mon.

### 2.2. Stand inventory: plot design and recorded data

For each of the two villages Hongphoy and Minyakshu, a fallow forest was selected which was ready for slashing and burning the following year. Since Hongphoy's Jhum cycle lasts nine years, comprising two years of cultivation and seven years of fallow, the recorded forest regrowth was seven years old, while the regrowth in Minyakshu with its Jhum cycle of seven years was five years old.

Additionally, one village forest in Hongphoy and one in Minyakshu and a natural forest stand in the proximity of Hongphoy were selected to collect data on the effects of different landuse forms on forest structure and productivity.

Within four of those five sampled forest stands, 25 plots of 20 m x 20 m were randomly distributed, leading to a total assessment area of one ha per forest stand, while the recorded Minyakshu village forest comprised 17 plots, thus 0.7 ha only. Within the recorded plots, all trees with a diameter at breast height (DBH, 1.3 m) $\geq$ 5 cm were measured. Further on, within each plot the natural regeneration was recorded on a subplot of 10 m by 10 m. Natural regeneration comprised all trees with a DBH < 5 cm and a height of $\geq$ 1.3 m.

The recorded silvicultural parameters for each tree comprised the local and the scientific name, DBH and for most trees total height. Damaged and dead trees were also included in the record of each stand. The diameter of buttressed trees was measured at 30 cm above buttresses and the diameter of tree sprouts with stool shoots such as *Alnus nepalensis* were measured at 10 cm above their buttress.

### 2.3. Forest data analysis

The structure of the five forest stands was characterised by the following parameters: basal area, arithmetic and quadratic mean diameter, mean height and top height (Van Laar and Akca, 1997). Missing tree heights were estimated by the height curve of Petterson (1955) that was fitted to each tree species in order to obtain estimated heights for those trees of which total heights were not measured during the survey. Total volume was calculated using a form factor of 0.5 (Loetsch et al., 1973) and the top height of the stand was calculated according to Hart (1928). The floristic structure was analysed with species-area curves and the importance value index (IVI) for each species after Curtis and McIntosh (1951). The IVI reflects dominance, abundance and frequency of each species per plot and allows comparing the relative importance of specific species within a single plot as well as among different stands (see Annex). Diversity within each stand was calculated with the Simpson (Simpson, 1949) and Shannon indices (Shannon and Weaver, 1949).

### 2.4. Semi-structured interviews and secondary data

In both villages 60 interviews were conducted with randomly selected households to obtain data on household size and fuelwood needs, measured in "baskets". Further questions addressed the source of fuelwood and the frequency of forest visits to collect specific non-timber forest products. Within each village the weight of 50 fuelwood baskets and the volume of wood it carried were also measured. Average density of wood was calculated according to specific tree species densities (Anonymous, 2009c).
Information on the actual land allocation in Nagaland and Mon District, population density and growth was gathered with the help of secondary data, mainly from statistical surveys of the Government of India (Directorate of Agriculture, 1991, Directorate of Economics and Statistics, 1995, Directorate of Economics and Statistics, 2001, Directorate of Wastelands, 2001, Director of Census Operations, 2001, Government of Nagaland, 2004).

## 3 Results and discussion

### 3.1 Comparative description of forest stands

#### 3.1.1 Fallow forest

At an altitude of 750 m a.s.l. the fallow stand at Hongphoy was dominated by *Macaranga indica* and *Saccharum spontaneum*, while the fallow stand at Minyakshu (1,500 m a.s.l.) was dominated by *Alnus nepalensis*, of which sprouts are cut during land clearing while the main stems are left behind (Table 2). Although this latter stand was two years younger than the seven year old fallow in Hongphoy, its total wood volume was five times higher. Nakro (2001) observed similar values for total tree volume in three stands in the Nagaland villages of Mohung, Mishilimi and Koio. While the five year old stand in Mohung was dominated by *A. nepalensis* and contained a total volume of 39.4 $m^3$, the other two stands without *A. nepalensis* had only a volume of 5.7 $m^3$ and 12.5 $m^3$, respectively. Within the fallow stand in Minyakshu *A. nepalensis* accounted for 25.0 $m^3$ (or 56%) of the total volume, while other secondary tree species had a total volume of 20.0 $m^3$. The important role of *A. nepalensis* for $N_2$-fixation in slash and burn systems was already discussed by Ramakrishnan (1992) and Cairns (2004) reported an intensification of the Jhum cycle due to *A. nepalensis* in the nearby village of Khonoma, where no apparent soil degradation was observed within a system of shifting cultivation comprising a two years cropping and a two years fallow period. Minyakshu's fallow forest contained more than 200 recently cut stems slashed for fuelwood by villagers who often did not even own the respective field. The number of regrowing tree species with a DBH < 5 cm and a minimum height of 1.3 m likely reflected the young succession phase of that fallow forest stand.

### 3.1.2 Village forest

Village forests in Nagaland are maintained for the supply of construction wood from selected tree and bamboo species, and for the collection of wild fruits and fuelwood. Those forests typically consist of different privately owned and sometimes even fenced plots. They are derived from primary forests which have been transformed by removing unwanted species and planting of valuable tree species such as *Dipterocarpaceae* which are taken from primary forests. Regrowth of undesired species is permanently removed and used for fuelwood. The village forest at Hongphoy is mainly used for the supply of bamboo and that at Minyakshu for construction wood (Table 2).

**Table 2.** Main stand parameters per hectare for two fallow forests, two village forests and a natural forest near the villages Hongphoy, Minyakshu and Wangla, Nagaland N.-E. India (2005).

| **Variable** | **Hongph. fallow** *(7 years old)* | **Minyak. fallow** *(5 years old)* | **Hongph. village forest** | **Minyak. village forest*** | **Wangla natural forest** |
|---|---|---|---|---|---|
| | | | *DBH ≥ 5 cm* | | |
| No. of trees | 612 | 1013 | 510 | 365 | 376 |
| No. of stems | 612 | 1633 | 512 | 365 | 409 |
| Arith. dia. (cm) | 7.0 ± 2.5 | 9.1 ± 3.1 | 12.8 ±9.2 | 21.3 ±12.5 | 22.6 ±14.9 |
| Quadr. dia. (cm) | 7.5 | 9.6 | 15.8 | 24.7 | 27.1 |
| Basal area ($m^2$) | 2.5 | 11.9 | 10.0 | 17.4 | 23.5 |
| Total volume ($m^3$) | 8.4 | 43.2 | 82.2 | 154.4 | 253.7 |
| Top height (m) | 8.0 | 8.3 | 17.9 | 19.3 | 24.6 |
| No. of cut stems | 28 | 215 | 48 | 258 | 35 |
| Vol. cut stems ($m^3$) | 0.3 | 3.6 | 8.8 | 71.4 | 12.9 |
| | | | *DBH < 5 cm and height ≥ 1.3 m* | | |
| Number of stems | 1440 | 1028 | 844 | 787 | 164 |
| Basal area ($m^2$) | 1.1 | 0.9 | 0.5 | 0.2 | 0.1 |
| Total volume ($m^3$) | 2.7 | 1.4 | 1.1 | 0.4 | 0.2 |
| No of cut stems | 16 | 168 | 0 | 126 | 4 |

* Forest inventory was done on 0.7 ha, presented data for number and volume of trees, basal area and number and volume of cut stems were calculated and refer to one hectare.

### 3.1.3 Natural forest

Remaining areas of natural forest were only found 500 m NW of Wangla, a village nearby Hongphoy at 550 m a.s.l. This natural forest belonged to the village chief. While customary laws prevent villagers from harvesting and collecting wood products in the natural forest, the village chief had started to log the natural forest in 1975. During the time of data collection, selected stems were again cut. Another logging cycle was planned for 2010 although the data assessment revealed little natural regrowth. Still the stand had a CDI > 70% and a total wood volume of 254 $m^3$ $ha^{-1}$ (Table 2).

3.1.4 Floristic composition and species diversity

Almost 48% of the 16,579 $km^2$ covered with forests in Nagaland have a CDI < 40% (State Forest Reports, 2005). These so called 'open forests' indicate the severe degradation of forested areas which is also reflected in reduced biodiversity (Figure 1).

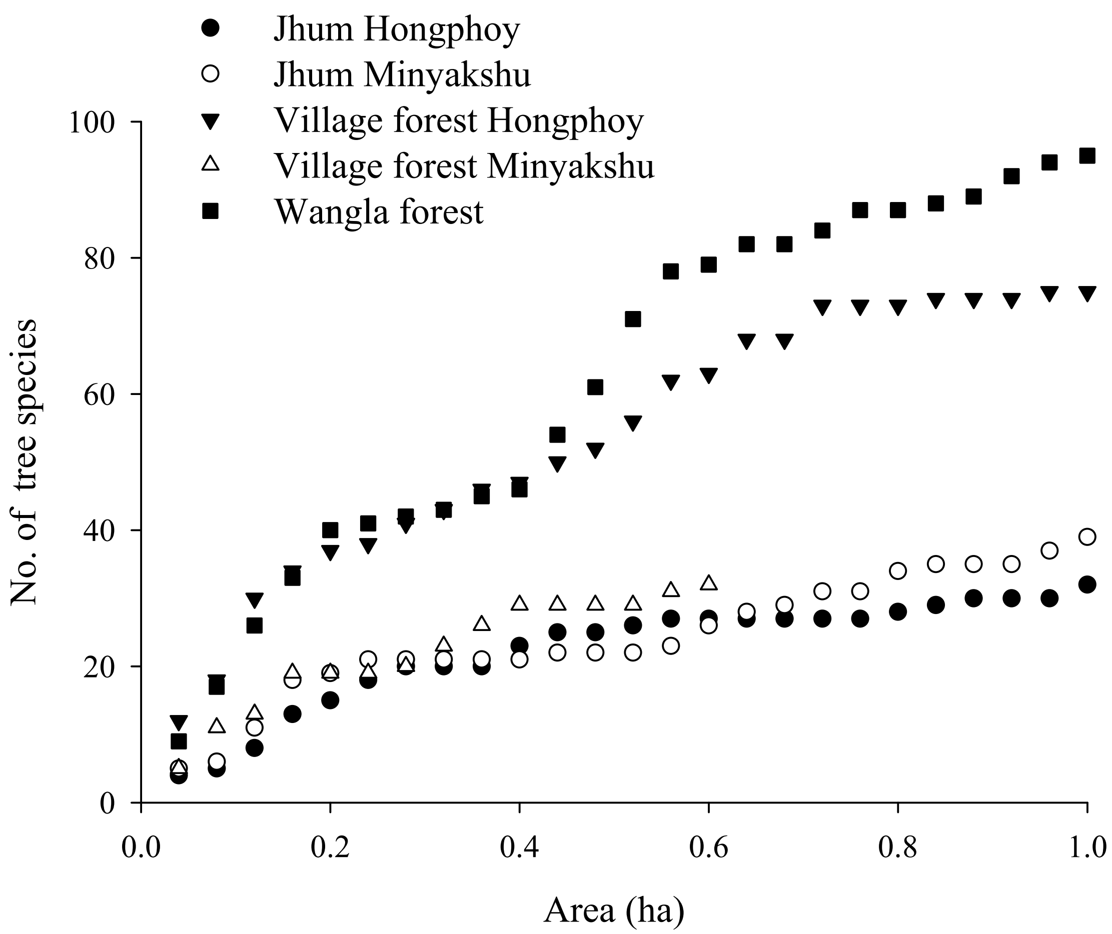



**Figure 1.** Species-area curve (accumulated number of tree species in accumulated area) for five forest types in Nagaland, N.-E. India (2005).

The investigated fallow forests contained the lowest number of species compared to the village forests and the natural forest (Figure 2). The data also indicate that a plot size of 1 ha may be representative for the tree flora since an expansion of the sample plot by 10% leads finally to an increase in the number of species < 10% (Cain and Oliveira Castro, 1956).

The low Simpson indices and the equally low Evenness figures reveal the low diversity of both fallow forests and the village forest in Minyakshu. The village forest in Hongphoy, in contrast, was characterized by much higher plant species diversity, similar to the investigated natural forest (Table 3).

**Table 3.** Tree species diversity in fallow forests, village forests and one natural forest in three villages of Nagaland, N.-E. India (2005).

| | **Number of trees** | **Number of species** | **Simpson Index [1-D]** | **Shannon Index [H']** | **Evenness [E] (%)** |
|---|---|---|---|---|---|
| *DBH ≥ 5cm, per ha, including cut stems* | | | | | |
| Hongphoy Jhum | 640 | 26 | 0.73 | 1.72 | 52.8 |
| Minyakshu Jhum | 1,848 | 30 | 0.70 | 1.59 | 46.8 |
| Minyakshu village forest | 374 | 30 | 0.61 | 1.80 | 53.1 |
| Hongphoy village forest | 560 | 71 | 0.94 | 3.41 | 79.9 |
| Wangla natural forest | 444 | 85 | 0.97 | 3.90 | 87.8 |
| *DBH < 5cm, per 0.25 ha* | | | | | |
| Hongphoy Jhum | 364 | 22 | 0.69 | 1.83 | 59.3 |
| Minyakshu Jhum | 299 | 29 | 0.85 | 2.45 | 72.9 |
| Minyakshu village forest | 228 | 19 | 0.84 | 2.22 | 75.3 |
| Hongphoy village forest | 211 | 37 | 0.94 | 3.04 | 84.2 |
| Wangla natural forest | 42 | 27 | 0.97 | 3.16 | 95.9 |

In the Jhum fallow forest of Hongphoy only three typical secondary forest species, *Macaranga indica, Litsea salicifolia* and *Mallotus nepalensis,* accounted for 251 of 300 percentage points of the IVI (Table in the Annex). The fallow forest in Minyakshu was dominated by *A. nepalensis,* and the secondary species *Sapium baccatum* and *Mallotus nepalensis.* These tree species represented 221 percentage points. Similarly, in the village forest of Minyakshu *Quercus polystachya,* Hymok and *Castanopsis* sp.

accounted for more than two thirds of the IVI (214 of 300). These three tree species are regarded by villagers as most durable and are thus predominantly cultivated for timber.

The village forest in Hongphoy was much more diverse with the most important species being *Schima wallichii, Duabanga grandiflora, Nyssa javanica*, *Terminalia myriocarpa* and the high value trees *Artocarpus heterophylla, Dipterocarpus retusus, Castanopsis purpurella* and *Shorea assamica*. The higher diversity and more even species distribution of this forest may be due to a strong demand for fruits and forest by-products since these can be easily marketed in Mon town. Hongphoy's village forest thus combined a high user value with species richness similar to the natural forest in Wangla.

In the Wangla forest 20 species represented two thirds of the IVI which is also mirrored in a high Simpson index and Evenness value. Most important species are *Aglaia hiernii*, *Ailanthus integrifolia, Stereospermum chelonoides.* High value species are *Dipterocarpus retusus, Shorea assamica, Anthocephalus chinensis, Stereospermum chelonoides, Castanopsis armata*, but most of them had only a low IVI due to the excessive logging of the stand.

### 3.2 Fuelwood needs and calculated minimum fallow area required for covering fuelwood needs

Our interviews revealed an average annual fuelwood consumption of 15,600 kg per family (equivalent to about 720 baskets, Table 4) in both villages. This was equivalent to per caput fuelwood consumptions of 2.7 $m^3$ per annum in Hongphoy (equivalent to 5.7 kg/day) and of 2.4 $m^3$ in Minyakshu (equivalent to 5.2 kg/day). Those values are much larger than the estimates of Nakro (2001) who reported a firewood use of only 1 $m^3$ per annum for three villages in Nagaland. Our values are also higher than those of Bhatt et al. (1994) who measured a daily per person wood consumption of 1.5 kg in the western Himalayas, of Reddy (1981) and Hedge (1984) with 1.9-2.2 kg for Southern India, of Mahat et al. (1987) with 1.2 kg for the Himalayan range of Nepal and of Donovan (1981) and Wijesinghe (1984) with 1.7-2.5 kg for several South and S.-E. Asian countries. The figures are, however, similar to those of Bhatt and Sachan (2004) with 3.9-5.8 kg for three tribal communities in N.-E. India, to those of Maikhuri

(1990) with 2.8-8.5 kg for families in Arunachal and to those of Maikhuri (1991) with 4.7 kg in Garos tribes of Meghalaya.

Based on the tree volume of fallow forest stands in Hongphoy and Minyakshu and the fuelwood needs in both villages, each person has a theoretical per caput requirement of 3,164 m² fallow forest in Hongphoy and of 560 m² fallow forest in Minyakshu to satisfy fuelwood demands. This calculation implies that all roundwood from fallow forests with a DBH above 5 cm is used for fuelwood although some resources have to be left behind in the field to construct contour lines. Material used for the construction of field huts is used as fuelwood at the end of the cultivation period.

**Table 4.** Fuelwood consumption *versus* wood volume of the fallow stands and theoretical minimum fallow field areas needed to satisfy fuelwood needs in the two villages of Hongphoy and Minyakshu, Nagaland, N.-E. India (2005).

| | | **Hongph. Jhum** | **Minyak. Jhum** |
|---|---|---|---|
| Medium weight of one fuelwood basket (kg) | 21.6 ± 6.3 | | |
| Average density of wood at 60% MC (kg/m³) | 778 | | |
| Volume of one basket (m³) | 0.028 | | |
| Consumption of fuelwood per family per year (baskets) | | 727 ±253 | 719 ±377 |
| Average family size (persons) | | 7.6 ±2.9 | 8.2 ±4.0 |
| Consumption per caput per year (baskets) | | 96 | 87 |
| Consumption per caput per year (m³) | | 2.7 | 2.4 |
| Consumption per caput per day (kg) | | 5.7 | 5.2 |
| Volume of trees DBH ≥ 5 cm per ha (m³) | | 8.4 | 43.2 |
| Number of baskets harvestable per ha | | 303 | 1,559 |
| Theoretical minimum fallow area required for covering fuelwood needs per caput (m²) | | 3,164 | 560 |
| Recorded fallow area per caput and year (m²) | | 1,039 | 549 |
| (Krug et al., unpublished) | | ±439 | ±458 |
| Per caput fuelwood gap considering fallow fields only (m³) | | 1.81 | 0.05 |

Although fuelwood needs seem similar in Hongphoy and Minyakshu, the per caput area requirement for fuelwood harvesting in the latter village is significantly lower than in the former. This is related to the higher stand volume per ha given the greater proportion of *A. nepalensis* in the forest stand.

In Hongphoy actual field sizes amounted to 1,039 $m^2$ per person in 2004 (Krug et al., unpublished) and are much below the 3,164 $m^2$ required to ensure that all fuelwood needs are met within the actual slashed fallow area. The high fuelwood requirements imply that an annual amount of 1.8 $m^3$ fuelwood per caput has to be harvested within forest areas outside the actual Jhum field. From the 60 families interviewed and respective field sizes measured in Hongphoy (Krug et al., unpublished), only 25 families owned fields of suitable sizes to cover their fuelwood requirements. This reflects the results of the interviews which showed that more than half of the families had to spend up to seven hours per day for the collection of fuelwood in remote areas. Other authors report similar data on average per caput fallow field sizes for Nagaland. The Directorate of Wastelands (2001) reports 510 $m^2$ and the Government of Nagaland (2001) 1,292 ±398 $m^2$.

### 3.3 Other fuelwood sources

Since there is a significant disproportion between fuelwood availability from Jhum fallows and fuelwood needs in Hongphoy, an estimated 2,279 $m^3$ fuelwood had to be collected in other areas to fulfil the yearly requirements of the 1,257 village habitants in 2005. This figure is most likely an underestimation since it is based on the assumption that all stems of a fallow area with a DBH above 5 cm are used for fuelwood, although some wood is also needed to construct contour lines within the steep fields. The quantity of 2,279 $m^3$ is similar to the total volume of 9 ha of Wangla's natural forest or another 271 ha of five year old fallow forests.

The fuelwood that is not collected within the Jhum field originates either from other fallow areas, from communal lands, open forests or wastelands, or from natural forest sites (Figure 2). However, fuelwood collection within natural forest sites is limited since these forests are often remote and owned by village chiefs or the Government of Nagaland, who prohibits wood cutting. The need for collecting fuelwood from outside the fallow areas might explain the vast areas of degraded forest sites in the Mon District.

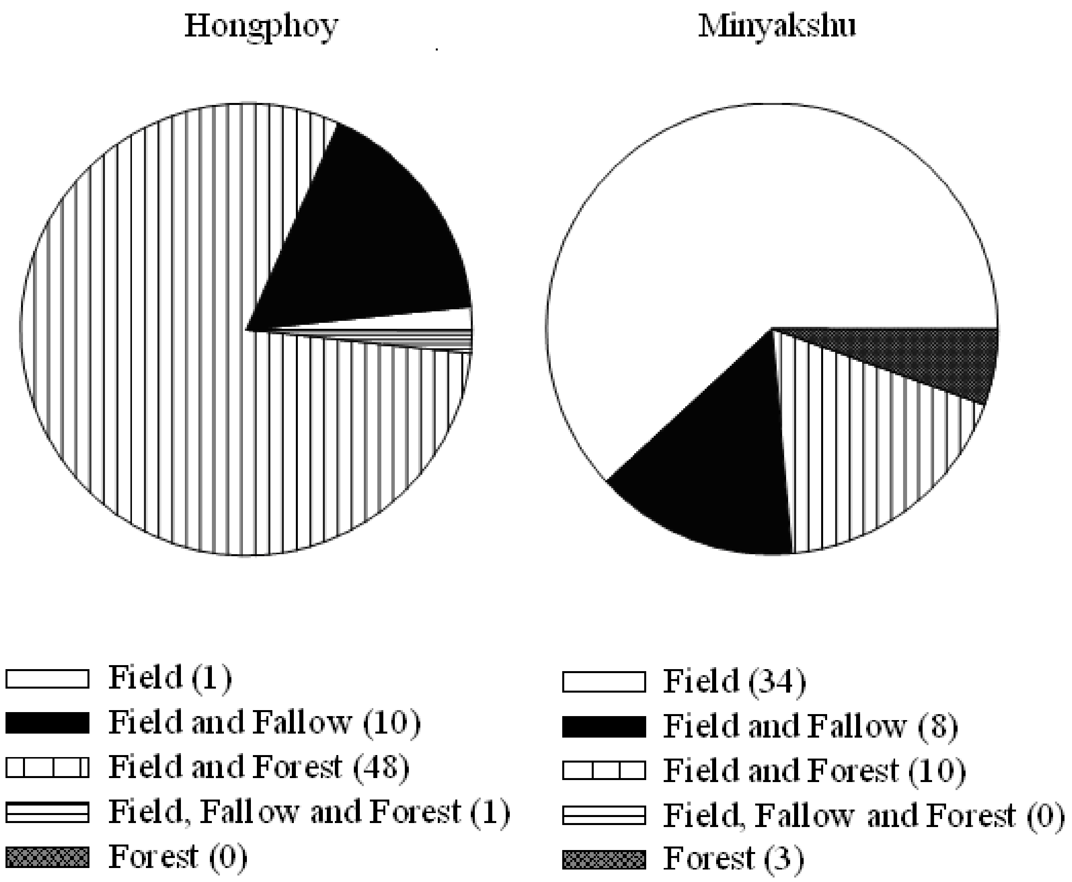



**Figure 2.** Sources of fuelwood according to 60 families interviewed in Hongphoy and 55 families interviewed in Minyakshu (Nagaland, N.-E. India) in 2005. The numbers in brackets show the number of households reporting the respective source: ‘Field’ refers to those areas that are slashed within the Jhum cycle, ‘Fallow’ are areas that should regenerate while ‘forest’ are areas that are not subject to shifting cultivation and are either natural forests or open lands that are often classified as wasteland.

While in Hongphoy only one family stated that the consumed fuelwood originated exclusively from the actual Jhum field, in Minyakshu more than half of the interviewed families stated that fuelwood from the fallow field was sufficient to satisfy people’s demand. This again indicates the fact that the gap between available stock of fuelwood on fallow fields is much larger in Hongphoy than in Minyakshu. Still even in Minyakshu some families had to satisfy fuelwood needs within other areas since fields are distributed unequally between families.

Our data reveal a theoretical annual fuelwood gap of 247 $m^3$ for the total of 5.253 villagers in Minyakshu. Although available areas are smaller per caput, land scarcity is less severe in this village since the volume of the fallow stand is much higher, most likely due to the abundant occurrence of *A. nepalensis*. Fallow stands enriched with this species might reduce the pressure on forest sites through fuelwood collection significantly (Cairns, 2004).

While in some villages Nagas cultivate their fields with *A. nepalensis* and are well aware about the benefits of this species, many neighbouring villages do not use alder trees. Changkija et al. (2000) report that only about 125 Nagaland villages are managing *A. nepalensis*, while Dhyani (1998) estimates about 22,000 ha of *A. nepalensis*-based agroforestry. Knowledge transfer between villages seems to be limited, which might be due to the long history of inter-tribal warfare.

## Conclusions

Within the Nagaland villages of Hongphoy and Minyakshu current fuelwood harvests on fallow fields are not sufficient to cover fuelwood demands due to short fallow periods and insufficient per caput fallow forest areas as a result of high population densities. Secondary data reveal a similar situation in other villages. The revealed fuelwood gap has to be filled from secondary forests and natural forests, entailing further degradation which results in even lower amounts of harvested fuelwood when those areas are finally slashed for agriculture.

In the past slash and burn agriculture and commercial timber logging has led to a severe decrease in forest cover and degradation of forest. Data of this study reveal the extend of subsequent degradation reflected in a decline of species diversity and stand volume. The village forest stand of Hongphoy managed for the supply of construction wood, non-timber products and fuelwood had a stand diversity comparable to the natural forest.

Data on Jhum fields in Minyakshu suggest that the tree volume of a stand can be significantly increased with planted *A. nepalensis*. Further research is needed to assess whether improved land use systems with alder trees might mitigate fuelwood scarcity to alleviate existing pressure on natural forest patches and forest regrowth areas.

**Acknowledgements**

We are indebted to the farmers of Hongphoy and Minyakshu who readily took part in interviews and field surveys. This work wouldn't have been possible without the support of Mr. Shing Wang Wangsha, Prince of Mon and Mr. Vengota Nakro and Mr. Kevin Zehoul, Neped project, Nagaland.

**Literature**

Anonymous(2009a). India Information, http://www.whereincity.com/india/ nagaland/mon.php (accessed on 25/01/2009).

Anonymous (2009b).General information, http://nagaland.nic.in/potential/tourism.htm (accessed on 25/01/2009).

Anonymous (2009c). Wood Density Database, http://www.worldagroforestrycentre. org/sea/Products/AFDbases/WD/Index.htm (accessed on 11/02/2009).

Anonymous (2009d). Biodiversity Hotspots, http://www.biodiversityhotspots.org/ xp/Hotspots/hotspotsScience/Pages/default. (accessed on 3/02/2009).

Bhatt, B.P. and Sachan, M.S. (2003), 'Fuelwood consumption along an altitudinal gradient in mountain villages of India', Agroforestry Division, ICAR Research Complex for NEH Region, Umiam, Meghalaya, India.

Bhatt, B.P. and Sachan, M.S. (2004), 'Fuelwood consumption pattern of different tribal communities in Northeast India', *Energy Policy* 32, 1-6.

Bhatt, B.P., Negi, A.K., Todaria, N.P. (1994), 'Fuelwood consumption pattern at different altitudes in Garhwal Himalaya', *Energy* 19(4), 465-468.

Cain, S.A. and Oliveira Castro, G.M. (1956), 'Application of some phytosociological techniques to brazilian rain forest', *Amer. Journal of Botany,* 43(10), 911-941.

Cairns, M. (2004), 'Fuel and fertility: Alder's role in land use intensification', Department of Anthropology, Research School of Pacific and Asian Studies, Australian National University, Canberra, Australia.

Census of India, (2001), Government of India, Registrar General & Census Commissioner, New Delhi, India.

Changkija, S., Yaden, A. and Aier, A. (2000), 'Indigenous sustainable agrforestry farming system based on alder tree (Alnus nepalensis) practised by the Nagas: a case study'. In: 'Agroforestry and forest products'. Proceedings of international workshop. India, Department of Forestry, NEHU, 43-52.

Curtis, J.T., McIntosh R.P. (1951), 'An upland forest continuum in the prairie-forest border region of Wisconsin.' *Ecology* 32, 476-498.

Dhrupad Choudhury and Sundriyal, R.C. (2003), 'Factors contributing to the marginalization of shifting cultivation in north-east India: micro-scale issues', *Outlook on Agriculture* 32(1), 17-28.

Dhyani, S.K. (1998), 'Tribal Alders: an Agroforestry System in the Northeastern Hills of India'. *Agroforestry Today* 10(4). Nairobi, Kenya: ICRAF.

Director of Census Operations (2001), 'Provisional Population Totals, Nagaland 2001', Census of India, Government of India, Delhi, India.

Directorate of Agriculture (1991), Government of Nagaland, Kohima, Nagaland, India

Directorate of Economics and Statistics (1995), 'Statistical Atlas of Nagaland, 1995', Directorate of Economics and Statistics, Government of Nagaland, Kohima, India.

Directorate of Economics and Statistics (2001), 'An Economic Survey of Nagaland, 2001', Directorate of Economics and Statistics, Nagaland, Kohima, India.

Directorate of Wastelands (2001), Government of Nagaland, Kohima, Nagaland, India.

Donovan, D.G. (1981), 'Fuelwood: How much Do We Need?' Institute of Current World Affairs, Hannover, NH, USA, p. 23.

Government of Nagaland (2004), 'Annual Administrative Report, 2003-2004', Department of Forest, Ecology, Environment & Wildlife, Kohima, Nagaland, India.

Government of Nagaland (2001), 'Village profile'. Excel file, Kohima, Nagaland, India.

Hart, M.J. (1928), 'Stamtalen dunning', Diss. Univ. Wageningen, Wageningen, The Netherlands.

Hedge, M.S. (1984), 'Fuel problem in villages: challenges and opportunities', *Bulletin of Science* 8, 8-13.

Krug, M., Schlecht, E, Bürkert. A. (unpublished), 'Agricultural sustainability and food security in Nagaland (N.E.-India)'.

Loetsch, F., Zöhrer, F. Haller, K.E. (1973). Forest Inventory. Vol 2. BLV Verlagsgesellschaft, München, Germany.

Mahat, T.B.S., Grigffin, D.M., Shepherd, K.P. (1987), 'Human impact on some forest of the middle hills of Nepal. Part 4: 'A detailed study in Southeast Sindhu Palanchock and Northeast Kabhere Palanchock', *Mountain Research and Development* 7, 114-134.

Maikhuri, R.K. (1990), 'Fuelwood consumption pattern of different tribal communities living in Arunachal Pradesh in North-East India', G.B. Pant Institute of Himalayan Environment & Development, HNB Garwhal University, Garwhal, India.

Maikhuri, R.K. (1994), 'Eco-energetic analysis of village ecosystem of different traditional societies of northeast India', *Energy* 21(12), 1287-1297.

Maikhuri, R.K. and Gangwar, A.K. (1991), 'Fuel wood use by different tribal and non-tribal communities in North-East India', *Natural Resources Forum* 15(2), 162-165.

Nakro, V. (2001), 'Adjustments of the Jhum system in Nagaland to increased population pressure', Thesis to obtain the Master of Science degree in Tropical Forestry at the Georg-August University, Göttingen, Germany.

Petterson, H. (1955), 'Yield of coniferous forests', *Medd. Stat. Skogsforsoksanct* 45 IB, Sweden.

Ramakrishnan, P.S. (1992), 'Shifting Agriculture and Sustainable Development', *Man and Biosphere Series* 10, Paris, France.

Ramakrishnan, P.S. and Kushawaha, S.P.S. (2001), 'Secondary forests of the Himalaya with emphasis on the North-Eastern Hill region of India', *Journal of Tropical Forest Science* 13(4), 727-747.

Ranjan, R. and Upadhyay, V.P. (1999), 'Ecological problems due to shifting cultivation', *Current Science* 77(10), 1246-1250.

Reddy, A.K.N. (1981), 'An Indian village agricultural ecosystem case study of Ungra village', Part II, Discussion. *Biomass* 1, 77-88.

Shannon, C. E., Weaver, W. (1949), 'The mathematical theory of communication'. Univ. of Illinois Press, Urbana, IL, USA.

Simpson, E.H. (1949), ‘Measurement of diversity.’ *Nature* 163, 688.

State of Forest Report (2005), ‘Forest Survey of India’, Ministry of Environment & Forests, Dehradun, India.

Toky, O.P. and Ramakrishnan, P.S. (1981), ‘Cropping and yields in agricultural systems of the North-Eastern hill region of India’, *Agro-Ecosystems* 7, 11-25.

Van Laar and Akca (1997), ‘Forest Mensuration’, Cuvillier, Göttingen, Germany, 418 pp.

Wastelands Atlas of India (2005), National Remote Sensing Agency, Dept. of Space, Govt. of India, Balanagar, Hyderabad, India.

Wijesinghe, L.C.A.des. (1984), ‘A sample study of biomass fuel consumption in Sri Lanka households’, *Biomass* 5, 261-282.

## Chapter 4:

# Conclusions

### Methodology

The presented study was carried out in a fairly remote area of India, where about little scientific information is available. Further on, research activities were carried out within several stays interrupted by clashes between underground fractions and the Indian Army. For this reason, e.g. the village forest of Minyakshu was inventoried on 0.7 ha only.

The methodology applied follows recommendations of other studies carried out in remote tropical regions for gaining basic information among traditional societies (compare e.g. Brodbeck, 2004; Lopez, 2003; Wode, 2000; Zickendraht, 1998; Apel, 1996). The information on forestry, agricultural and population data, however, can reflect the described environment on a case study basis only.

The lack of basic quantitative information like e.g. total area sizes of forest stands leads to uncertainties. It is a common practice under comparable circumstances (compare Brodbeck, 2004; Lopez, 2003; Wode, 2000; Zickendraht, 1998; Apel, 1996) to determine the number of plots needed by the species area curve for identifying a representative minimum area (Cain and Oliveira Castro, 1956). The randomised plots within an identified forest area must therefore be regarded as a number of small case studies rather than repetitions within a designated population.

The agricultural data discussed comprises measured field sizes and amounts of harvested main crops (rice (*Oryza sativa* L.), pearl millet (*Pennisetum glaucum* L.) and maize (*Zea mays* L.)). Secondary crops such as yams (*Dioscorea* spp.), cassava (*Manihot esculenta* Crantz), cucumber (*Cucumis sativus* L.), ginger (*Zingiber officinale* Roscoe), chilli pepper (*Capsicum annum* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum&Nakai), pumpkin (*Cucurbita* spp.), mustard (*Brassica juncea* (L.) Czern), sweet potato (*Ipomoea batatas* L.) and various pulses were recorded as well during interviews but the information was not used later on. While the harvested baskets of the main crops rice, pearl millet and maize are well counted and recorded every year by the church for taxation purposes, villagers' statements on the harvested amounts of secondary crops obviously reflected rough estimations rather than counts. The reliability of the presented data would have been improved by own quantitative measurements for all cereal and non-cereal crops, which was however not possible since the study was not carried out in the harvesting season.

The management of *Alnus nepalensis* in forest stands obviously resulted in higher timber yields as those presented in Chapter 3. In addition to that, Cairns (2004) reported an improved yield on rice fields stocked with *Alnus nepalensis*. He observed "a dramatic intensification of the Jhum cycle to as short as '2 years cropping : 2 years fallow' without any apparent soil degradation. This intensified cultivation nearby the village meant that the remaining 70% of Khonoma's land was not needed for jhumming and thus conserved as communal forests" (Cairns, 2004).

Such information highlights the potential and importance of improved cultivation methods. Especially the land productivity might be increased substantially through the use of soil amendments. However, the use of mineral fertiliser is not possible due to financial constraints and the lack of a related infrastructure in Nagaland. Animal dung is not used as fertiliser since only few families are able to afford pigs or even cows. Within the described Jhum system, soil improvement is only supported by the fallow period, the input of nutrients by burning and obviously by an improved fallow with *Alnus nepalensis*.

Detailed investigations on the impact of *Alnus nepalensis* on soil chemical characteristics could have provided valuable information. Approaches like e.g. the use of soil samples within reversed time series was not planned at first stage, but the results of the present studies highlight the need for further research.

**Fulfilment of cereal and fuelwood needs within a system of shifting cultivation (Jhum)**

There is an ongoing discussion among Indian politicians and scientists whether the system of shifting cultivation that is in general well adopted to the hilly terrain of Nagaland might be a stable, sustainable system under certain preconditions or whether it should be replaced in favour of agroforestry or production of cash crops. There is agreement on the fact that population density is the key factor deciding whether the system is sustainable or not. During the times of the British in 1900, farmers were even able to harvest an agricultural surplus and tended to have many children to gain agricultural labour force (Jacobs, 1990). At those times the Naga tribes were living fairly undisturbed and with little outside influence due to the geographic conditions of the Naga hills and the Naga's reputation of being headhunters. Neighbouring tribes avoided crossing the densely forested hills of Nagaland, and even the modern Government of India proclaims Nagaland as restricted area to avoid interference with the Naga tribes' culture and lifestyle. However, since population growth was steeply increasing within the last decades, the Naga tribes are faced with the severe degradation of those resources that provided the basis of their livelihoods.

As no additional arable land is available within Nagaland for expanding the area under shifting cultivation and only little alternative income opportunities exist, the Naga are facing the fate of many other forest dwelling tribes of impoverishment, land and resource degradation and loss of cultural integrity. As illustrated by Angelsen and Wunder (2002), forested environments can provide a "safety net" for the rural poor, but it proves difficult to raise producer benefits significantly. The consequence is, often enough, an increased out-migration of people. However, such final consequences as the migration to cities and other areas to escape land pressure and poverty, which are mainly taken up by the younger population, are not necessarily leading to reduced impoverishment and land degradation as long as the majority of the reproducing population remains. Due to the pressure on natural resources, the remaining population will still suffer unsatisfied demands and are forced to return to a basic subsistence level once population growth has outpaced agricultural production. This situation becomes even more severe in the light of the globally increasing price for basic commodities and expected constrains for agriculture by effects of climate change.

Slash and burn agriculture and timber logging has already led to a severe decrease in forest cover and to forest degradation as described by the State of Forest Report (2005). Data of this study describing different forest stands in Nagaland reveal the extent of qualitative forest losses with regard to species diversity and richness. Further on, the fuelwood harvests on actual fallow fields are not sufficient to cover fuelwood demands within the villages of Hongphoy and Minyakshu due to shortened fallow periods and insufficient per caput areas as a result of high population densities. Secondary data reveal a similar situation in other villages in the region. The existing gap between fuelwood demand and availability from fallow fields has to be supplied by secondary forests and natural forests, causing a further degradation of those. Summarizing these results, deforestation and forest degradation are understood as direct consequences of intensified agricultural activities and an increased fuelwood demand, both resulting from the basic requirements of an increasing population.

The presented data on agricultural yield levels and energy intake show the severe constraints to food security in the two Nagaland villages of Hongphoy and Minyakshu, whose agricultural carrying capacity at the current level of land productivity is reached if not already exceeded. The main cause of this development is the extraordinary high rate of population growth resulting from traditionally high birth rates combined with a decrease in infant mortality. Programmes to facilitate access to family planning methods within remote villages are not in place. Further on, farmers tend to link a large number of children to a rising status of the family and a gain in labour force.

Scarceness of cereals is not only explained by the limited availability of arable land, but is also due to lowered soil productivity as a consequence of shortened fallow periods. The customary coping strategy of taking more land under cultivation is not possible anymore since no additional arable land is available for further Jhum cultivation. In Hongphoy in 2004 each person consumed 190 kg of rice (harvested and purchased), millet and maize, leading to a mean daily energy consumption of 10,450 Joule (±3,300) that was regarded as satisfactory by the villagers. Harvests in the following year and the harvests in Minyakshu in both years were insufficient to satisfy such an energy demand. The following table (Table 1) illustrates the gap between harvested amounts of cereals compared to a cereal quantity equivalent to the daily requirement of 10,450 Joule per caput and the quantity of rice needed to compensate lower harvests.

**Table 1.** Energy derived from harvests compared to a target value of 10,450 Joule per caput and day and the amount of purchased rice needed to compensate insufficient harvests. Reference is made to Foster's (1992) relation[1], that food-security is maintained as long as the monetary equivalent of the harvest-gap is lower than or equal to the monetary income.

| Per head | **Hongphoy 2004** | **Hongphoy 2005** | **Minyakshu 2004** | **Minyakshu 2005** |
|---|---|---|---|---|
| Energy derived from harvested cereals per caput and day (Joule) | 9,129 | 7,299 | 6,823 | 6,376 |
| Gap compared to 10,450 Joule (Joule) | -1,371 | -3,200 | -3,677 | -4,124 |
| Equivalent in cereals (kg) | -0.093 | -0.217 | -0.249 | -0.279 |
| Cereals that have to be bought per caput and year (kg) | 34 | 79 | 91 | 102 |
| Monetary equivalent (€) | 8 | 20 | 23 | 25 |
| Monetary income per caput and year (€) | 50 | 45 | 40 | - |

Table 1 indicates the monetary income needed for compensating shortages in harvested cereals. According to Foster's (1992) equation, the status of food security in the studied Naga villages would not classify as a crucial situation. It must be considered, however, that the monetary income reflects the total income which is meant to cover various essential goods, like school fees, medicine, clothes, non-subsistence foodstuff like sugar, oil and tea, as well as any other commodities. Hence the monetary income does actually not allow for sufficient compensation of low harvests. This, in turn, reveals the increased vulnerability of the Nagas in the light of potential harvest losses due to calamities or shortfalls in monetary income, or especially to rising rice prices.

[1] Foster (1992) defines food security (FS) as follows:

FS = (Food consumption requirement - Food production) * Price of food ≤ income & liquid assets available to purchase food.

Unless land productivity can be substantially increased through the targeted use of soil amendments leading to higher yields, the food demand of Nagaland's rapidly growing population will increasingly depend on purchased rice, requiring a substantial rise in households' off-farm income.

However, the harvested tree volume of a fallow stand can be significantly increased with *Alnus nepalensis* as data on Jhum fields in Minyakshu suggest. Further research is needed to assess whether improved land-use systems with alder trees might mitigate fuelwood scarceness and increase cereal harvest to enhance soil fertility and lower existing pressure on natural forest patches and forest regrowth.

**References**

Angelsen, A. and Wunder, S. (2002), 'Exploring the forest-poverty link'. *CIFOR, Occasional Paper 40*. Bogor.

Apel, U. (1996), 'Der Dorfwald von Moxie: Traditionelle Dorfwaldbewirtschaftung in Xishuangbanna, Südwest-China'. *Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen* 108. Göttingen.

Brodbeck, F. (2004), 'Structure and Processes in Traditional Forest Gardens of Central Sulawesi, Indonesia'. Göttingen.

Cain, S.A. and Oliveira Castro, G.M. (1956), 'Application of some phytosociological techniques to Brazilian rain forest', *Amer. Journal of Botany,* 43(10), 911-941.

Cairns, M. (2004), 'Fuel and fertility: Alder's role in land use intensification', Department of Anthropology, Research School of Pacific and Asian Studies, Australian National University, Canberra, Australia.

Foster, P. (1992), 'The World Food Problem: Tackling the causes of undernutrition in the Third World'. Boulder, Colo., USA: Lynne Rienner Publishers, 367 pp.

Jacobs, J. (1990), 'The Nagas, Hill Peoples of Northeast India: Society, Culture and the Colonial Encounter', London.

Lopez, P. (2003), 'Sekundäre Trockenwälder in Nordmadagaskar – eine Fallstudie über ihre Strukturen, Potentiale und Nutzungsformen'. *Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen* 148. Göttingen.

State of Forest Report (2005), 'Forest Survey of India, Ministry of Environment & Forests, Dehradun'.

Wode, B. (2000), 'Traditionelle Waldnutzung der Halang-Minderheit im Wandel – eine Fallstudie am Mount Ray im Zentralen Hochland von Vietnam'. *Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen* 141. Göttingen.

Zickendraht. M. (1998), 'Der traditionelle Dorfwald in den tropischen/subtropischen Bergregionen der Provinz Yünnan, VR China, unter dem Aspekt der Nachhaltigkeit'. *Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen* 129. Göttingen.

**Attachment:**

Importance Value Index (IVI) of tree species in the fallow forests and village forests of Hongphoy and Minyakshu and one natural forest of Wangla in 2005.

| Hongphoy Jhum | Dominance ($m^2$) | Abundance (n) | Frequency (%) | IVI |
|---|---|---|---|---|
| *Trees with DBH ≥ 5 cm (1 ha plot)* | | | | |
| *Macaranga indica* | 1.16 | 233 | 96 | 100.2 |
| *Litsea salicifolia* | 0.81 | 212 | 96 | 84.4 |
| *Mallotus nepalensis* | 0.30 | 95 | 60 | 39.4 |
| *Schima wallichii* | 0.20 | 1 | 4 | 8.2 |
| *Macaranga peltata* | 0.03 | 14 | 20 | 8.0 |
| *Drimycarpus racemosus* | 0.03 | 14 | 20 | 8.0 |
| *Ficus hispida* | 0.05 | 10 | 16 | 7.0 |
| *Callicarpa macrophylla* | 0.03 | 8 | 16 | 6.0 |
| *Alseodaphne andersonii* | 0.03 | 8 | 12 | 5.1 |
| Ubah* | 0.02 | 6 | 12 | 4.5 |
| *Total of 10 species with highest IVI* | *2.66* | *601* | *352* | *270.8* |
| *Total of remaining 16 species* | *0.12* | *36* | *84* | *29.2* |
| *Total of 26 species* | *2.78* | *637* | *436* | *300.0* |
| *Trees with Height ≥ 1.3 m and DBH < 5 cm (0.25 ha subplot)* | | | | |
| *Macaranga peltata* | 0.13 | 195 | 24 | 111.1 |
| *Litsea salicifolia* | 0.03 | 29 | 44 | 39.9 |
| *Mallotus nepalensis* | 0.04 | 38 | 16 | 32.0 |
| *Macaranga indica* | 0.02 | 20 | 36 | 28.0 |
| *Phoebe lanceolata* | 0.01 | 17 | 4 | 10.4 |
| *Ficus hispida* | 0.00 | 8 | 12 | 9.3 |
| *Alchornea tiliaefolia* | 0.01 | 10 | 4 | 9.1 |
| *Callicarpa macrophylla* | 0.01 | 6 | 8 | 8.5 |
| *Drimycarpus racemosus* | 0.01 | 6 | 8 | 7.4 |
| *Elaeagnus pyriformis* | 0.00 | 6 | 8 | 6.8 |
| *Total of 10 species with highest IVI* | *0.26* | *335* | *164* | *262.6* |
| *Total of remaining 12 species* | *0.02* | *29* | *48* | *37.4* |
| *Total of 22 species* | *0.28* | *364* | *212* | *300.0* |

*scientific name not identified

| Minyakshu Jhum | Dominance (m²) | Abundance (n) | Frequency (%) | IVI |
|---|---|---|---|---|
| | *Trees with DBH ≥ 5 cm (1 ha plot)* | | | |
| *Alnus nepalensis* | 6.42 | 707 | 100 | 101.3 |
| *Sapium baccatum* | 4.37 | 698 | 100 | 85.4 |
| *Mallotus nepalensis* | 1.01 | 220 | 100 | 34.7 |
| Yitphao* | 0.34 | 68 | 56 | 14.8 |
| Hymok* | 0.29 | 36 | 36 | 9.7 |
| *Rhus semialata* | 0.06 | 16 | 40 | 7.4 |
| *Trema orientalis* | 0.13 | 14 | 32 | 6.6 |
| Onkonpongpo* | 0.11 | 18 | 24 | 5.5 |
| Lubiang* | 0.07 | 12 | 20 | 4.3 |
| *Radermachera gigantea (Bl.)* | 0.08 | 21 | 12 | 3.6 |
| *Total of 10 species with highest IVI* | *12.88* | *1,810* | *520* | *273.3* |
| *Total of remaining 20 species* | *0.46* | *65* | *128* | *26.7* |
| *Total of 30 species* | *13.34* | *1,875* | *648* | *300.0* |
| | *Trees with Height ≥ 1.20 m and DBH < 5 cm (0.25 ha subplot)* | | | |
| *Sapium baccatum* | 0.09 | 93 | 40 | 79.5 |
| *Alnus nepalensis* | 0.06 | 52 | 48 | 53.6 |
| *Mallotus nepalensis* | 0.02 | 24 | 52 | 32.0 |
| *Radermachera gigantea (Bl.)* | 0.02 | 25 | 12 | 18.9 |
| Onkonpongpo* | 0.01 | 20 | 16 | 15.9 |
| Najong* | 0.00 | 14 | 0 | 6.1 |
| Yitphao* | 0.01 | 7 | 8 | 7.5 |
| *Trema orientalis* | 0.01 | 6 | 20 | 9.9 |
| Ikhipo* | 0.00 | 6 | 12 | 8.1 |
| Hymok* | 0.00 | 5 | 12 | 7.1 |
| *Total of 10 species with highest IVI* | *0.23* | *252* | *220* | *238.7* |
| *Total of remaining 19 species* | *0.03* | *47* | *108* | *61.3* |
| *Total of 29 species* | *0.26* | *299* | *328* | *300.0* |

*scientific name not identified

| Hongphoy village forest | Dominance (m²) | Abundance (n) | Frequency (%) | IVI |
|---|---|---|---|---|
| *Trees with DBH ≥ 5 cm (1 ha plot)* | | | | |
| *Schima wallichii* | 2.28 | 103 | 72 | 45.2 |
| *Duabanga grandiflora* | 1.22 | 31 | 32 | 19.2 |
| *Nyssa javanica* | 1.02 | 31 | 44 | 18.7 |
| *Terminalia myriocarpa* | 0.38 | 43 | 40 | 15.0 |
| *Eugenia ramosissima* | 0.28 | 24 | 60 | 12.8 |
| *Artocarpus heterophylla* | 0.80 | 15 | 32 | 12.7 |
| *Dipterocarpus retusus* | 0.19 | 29 | 56 | 12.6 |
| *Michelia doltsopa* | 0.14 | 31 | 48 | 11.7 |
| *Castanopsis purpurella* | 0.32 | 19 | 40 | 10.2 |
| *Toona ciliata* | 0.22 | 14 | 32 | 7.7 |
| *Total of 10 species with highest IVI* | *6.85* | *340* | *456* | *165.8* |
| *Total of remaining 61 species* | *4.92* | *220* | *516* | *134.2* |
| *Total of 71 species* | *11.77* | *560* | *972* | *300.0* |
| *Trees with Height ≥ 1.3 m and DBH < 5 cm (0.25 ha subplot)* | | | | |
| *Schima wallichii* | 0.02 | 33 | 32 | 37.3 |
| *Michelia doltsopa* | 0.01 | 20 | 40 | 27.8 |
| *Litsea laeta* | 0.01 | 22 | 24 | 27.6 |
| *Dipterocarpus retusus* | 0.01 | 12 | 28 | 23.4 |
| *Terminalia myriocarpa* | 0.01 | 16 | 24 | 22.2 |
| *Nyssa javanica* | 0.01 | 12 | 24 | 17.5 |
| *Eugenia ramosissima* | 0.01 | 7 | 24 | 14.1 |
| *Gmelina arborea* | 0.01 | 9 | 20 | 13.9 |
| *Toona ciliata* | 0.01 | 5 | 20 | 11.6 |
| *Canarium strictum* | 0.00 | 8 | 16 | 11.0 |
| *Total of 10 species with highest IVI* | *0.09* | *144* | *252* | *206.4* |
| *Total of remaining 27 species* | *0.03* | *67* | *140* | *93.6* |
| *Total of 37 species* | *0.13* | *211* | *392* | *300.0* |

| Minyakshu village forest | Dominance (m²) | Abundance (n) | Frequency (%) | IVI |
|---|---|---|---|---|
| | *Trees with DBH ≥ 5 cm (0.7 ha plot)* | | | |
| *Quercus polystachya* | 10.18 | 228 | 93 | 144.9 |
| Hymok* | 3.61 | 41 | 73 | 48.5 |
| *Castanopsis sp.* | 0.19 | 28 | 60 | 20.3 |
| *Lindera caudate* | 0.12 | 12 | 40 | 11.7 |
| *Ficus sp.* | 0.05 | 10 | 27 | 8.1 |
| *Eurya acuminate* | 0.09 | 9 | 27 | 8.1 |
| *Betula alnoides* | 0.44 | 3 | 20 | 7.5 |
| *Castanopsis myriocarpa nrf* | 0.10 | 4 | 13 | 4.3 |
| *Castanopsis myriocata* | 0.30 | 3 | 7 | 4.0 |
| *Actinodaphne angustifolia* | 0.08 | 3 | 13 | 3.9 |
| *Total of 10 species with highest IVI* | *15.16* | *341* | *373* | *261.3* |
| *Total of remaining 20 species* | *0.26* | *33* | *147* | *38.7* |
| *Total of 30 species* | *15.42* | *374* | *520* | *300.0* |
| | *Trees with Height ≥ 1.3m and DBH < 5 cm (0,25 ha subplot)* | | | |
| *Betula alnoides* | 0.02 | 43 | 67 | 86.5 |
| *Ficus sp.* | 0.00 | 24 | 53 | 40.2 |
| Tuongpo* | 0.01 | 12 | 53 | 35.0 |
| Singtien* | 0.00 | 16 | 40 | 26.6 |
| *Sauropus macrophyllus* | 0.00 | 6 | 40 | 17.7 |
| *Eurya acuminate* | 0.00 | 6 | 13 | 14.8 |
| *Mallotus nepalensis* | 0.00 | 10 | 7 | 13.2 |
| *Ficus pomifera* | 0.00 | 3 | 20 | 8.5 |
| Onkongpo* | 0.00 | 4 | 13 | 8.3 |
| Nusiak* | 0.00 | 2 | 7 | 7.1 |
| *Total of 10 species with highest IVI* | *0.04* | *126* | *313* | *257.9* |
| *Total of remaining 9 species* | *0.01* | *11* | *67* | *42.1* |
| *Total of 19 species* | *0.05* | *137* | *380* | *300.0* |

*scientific name not identified

| Wangla natural forest | Dominance ($m^2$) | Abundance (n) | Frequency (%) | IVI |
|---|---|---|---|---|
| *Trees with DBH ≥ 5 cm (1 ha plot)* | | | | |
| *Aglaia hiernii* | 0.77 | 36 | 64 | 23.4 |
| *Ailanthus integrifolia* | 1.00 | 25 | 40 | 21.3 |
| *Stereospermum chelonoides* | 0.69 | 23 | 52 | 18.4 |
| *Firmiana colorata* | 0.51 | 13 | 40 | 12.8 |
| *Arelia sp.* | 0.27 | 21 | 48 | 12.5 |
| *Canarium strictum* | 0.22 | 15 | 32 | 9.0 |
| *Albizzia lebbek nrf* | 0.35 | 10 | 24 | 8.7 |
| *Michelia doltsopa* | 0.29 | 12 | 24 | 8.4 |
| *Altingia excelsia* | 0.31 | 12 | 16 | 7.9 |
| *Ficus auriculata* | 0.13 | 16 | 28 | 7.8 |
| *Total of 10 species with highest IVI* | *4.54* | *183* | *368* | *130.2* |
| *Total of remaining 75 species* | *3.82* | *260* | *696* | *169.8* |
| *Total of 85 species* | *8.35* | *443* | *1064* | *300.0* |
| *Trees with Height ≥ 1.3 m and DBH < 5 cm (0.25 ha subplot)* | | | | |
| *Michelia doltsopa* | 0.0 | 3 | 12 | 27.4 |
| *Aglaia hiernii* | 0.0 | 4 | 12 | 27.2 |
| *Arelia sp. (1)* | 0.0 | 3 | 12 | 24.1 |
| *Ficus fistulosa* | 0.0 | 3 | 4 | 22.8 |
| *Juglans regia L. var. kumaonia* | 0.0 | 2 | 8 | 15.2 |
| *Macaranga denticulata* | 0.0 | 1 | 4 | 13.0 |
| Nahum * | 0.0 | 3 | 8 | 13.0 |
| Niai* | 0.0 | 1 | 4 | 11.8 |
| *Arelia sp. (2)* | 0.0 | 2 | 4 | 11.2 |
| *Friesodielsia fornicata* | 0.0 | 2 | 8 | 11.0 |
| *Total of 10 species with highest IVI* | *0.02* | *24* | *76* | *176.7* |
| *Total of remaining 17 species* | *0.01* | *18* | *68* | *123.3* |
| *Total of 27 species* | *0.02* | *42* | *144* | *300.0* |

*scientific name not identified

I assure that this dissertation was written independently and without non-permissible help and that I used no sources other than those specified in the dissertation. All quotations that have been extracted from published or unpublished sources have been marked as such. No part of this work has been used in other PhD processes.

Hiermit versichere ich, dass ich die vorliegende Dissertation selbständig und ohne unerlaubte Hilfe angefertigt und keine anderen als die in der Dissertation angegebenen Hilfsmittel benutzt habe. Alle Stellen, die aus veröffentlichten oder unveröffentlichten Schriften entnommen sind, habe ich als solche kenntlich gemacht. Kein Teil dieser Arbeit ist in einem anderen Promotionsverfahren verwendet worden.

Witzenhausen, 14st of May 2009
Maike Krug