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Patterns and determinants of agricultural systems in the Chittagong Hill Tracts of Bangladesh

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Abstract

Against the backdrop of environmental degradation and poverty caused by traditional agricultural systems in the mountain regions, this study classified agricultural systems in the Chittagong Hill Tracts of Bangladesh and analyzed their determinants, with the objective of seeking policies for environmentally compatible and economically viable agricultural systems. Information was collected from 36 tribal villages of Bandarban district through household survey, group discussion, observation, key informant interview, and secondary sources. In view of the complex heterogeneity of prevailing agricultural systems in the surveyed villages, systems were classified into three major groups – extensive, semi-extensive and intensive – using cluster analysis. The factors determining these three types of agricultural systems were analyzed using factor analysis. Discriminant analysis was performed to explore the relative influence of these predicted factors. Institutional support, including land tenure, extension services and credit facilities, productive resource base and the distance to the market and service centres were found to be the major factors influencing agricultural systems in the study area. Provision of appropriate institutional support, including a secure system of land tenure, is indispensable for enabling poor mountain farmers to adopt environmentally and economically sound intensive agricultural systems such as plantation, agroforestry and livestock

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husbandry. Emphasis is also laid on linking mountain regions to other regions through the development of infrastructure such as roads.

Keywords: Agricultural systems; Shifting agriculture; Determinants of agricultural systems; Chittagong Hill Tracts; Bangladesh

1. Introduction

Mountains have significant ecological, aesthetic, and socioeconomic importance not only for the people living there but also for the people living beyond. About 10% of the world's people depend directly on the use of mountain resources for their well-being, and perhaps 40% depend indirectly on mountains for water, hydroelectricity, timber, mineral resources, recreation, and flood control (Ives, 1985). Mountains are also home to millions of people, a substantial proportion of whom are indigenous ethnic minorities eking out their livelihoods by utilizing the natural resources available there. Some 65% of the rural population of Asia, and a much larger percentage of its poor, live in upland regions (Douglas, 1999). To what extent or for how long the ecosystem-balancing and economic opportunity-generating roles of mountains will continue depends on the status of natural resources such as the forest and farmlands found there. There is a need for sustainable use and management of mountain resources. Special attention needs to be paid to farmlands, as they occupy a substantial portion of the mountains and are being regularly used by millions of people in the pursuit of securing livelihoods.

The condition of farmlands and the economic return from them depend directly on how these resources are being used and on what kind of agricultural systems are being practised. In several mountain regions, shifting cultivation is still actively practised, though it has undergone substantial changes in its characteristics. Shifting cultivation in its original form, with a long fallow cycle of 15–20 years, was an environmentally compatible agricultural system, as it did not deter the growth of secondary forest. With the shortening of the fallow period under the pressure of steadily increasing population and restriction on local people's access to forest through their nationalization, shifting cultivation in many places has become an environmentally and economically incompatible practise (Rasul and Thapa, 2003). In the mountains of Laos where shifting cultivators used to keep land fallow for up to 15–20 years until a few decades ago, nowadays they mostly keep land fallow for three years because of a government ban on keeping land fallow for more than three years, increasing population pressure and nationalization of forest (Chazee, 1994). As a result, there are no prospects for regeneration of forest and soil fertility (Charlton, 1987; Sanchez, 1994). Moreover, because of increased land-use intensity without any management practise, the pace of soil erosion has increased considerably. In the Nam Ngum watershed of Laos, 28.6 million tons of soil are lost every year at the rate of 36.6 tons/ha (BCEOM/SEATEC/SEMED, 1999). Growing evidence suggests that shifting cultivation with short fallow period leads to adverse effects on soil and water by altering the physical (Alegre and Cassel, 1996) and chemical properties of soil (Juo and Manu, 1996; Holscher et al., 1997), reducing nutrient stocks, and accelerating soil erosion (Baker, 1984; Gafur, 2001). In the Chittagong Hill Tracts of Bangladesh, where shifting cultivation is the dominant type of agricultural system, growing annual crops on steep slopes by slash-and-burn, which are otherwise suitable for perennial crops, has led to accelerated deforestation, soil erosion and nutrient depletion, resulting in declining yield and income of the poor tribal people (Uddin et al., 2000; Gafur, 2001; Knudsen and Khan, 2002). Because of very low returns from agriculture, shifting cultivators have to depend on forest products to fulfill their subsistence requirements (Chazee, 1994).

In the mountains of Nepal, shifting cultivation has been replaced by a field crop cultivation system integrated with livestock. Carefully managed agricultural systems, including the construction of extensive terraces, which evolved as a response to the ever-increasing demand for food arising from steady population growth, have controlled agricultural land degradation to a considerable extent and helped to enhance food supply. However, the non-irrigated terraces characterized by relatively wide and outward facing slopes have been undergoing accelerated soil erosion at the rate of 5–20 t/ha/yr (Carson, 1992), as soil structure is frequently disturbed by the regular hoeing and ploughing operations required for growing cereal crops. Despite intensive efforts to increase agricultural production, most of the hill people have not been able to fulfill their subsistence requirements. However, in some locations in the mountainous areas of Nepal, farmers have been enjoying increased income keeping dairy cattle and integrating commercial tree crops with cereal crops (Thapa and Paudel, 2000; Neupane and Thapa, 2001). The situation is similar in the Chittagong Hill Tracts of Bangladesh, hereafter refereed to as CHT, (Rasul, 2003) and in the northern mountains of Thailand (Turkelboom et al., 1996). While shifting cultivation is still the dominant type of agricultural system in CHT, in several places it has been gradually replaced by more remunerative and environmentally compatible agricultural systems such as horticulture, agroforestry, and timber plantations integrated with cereal crops (Rasul, 2003). The question arises as to why in some areas people have continued practising shifting cultivation, while in other areas they have been gradually shifting to more remunerative agricultural systems.

The challenge for agricultural policymakers and planners, particularly in the context of the mountains, is how to enable people to adopt more economically attractive agricultural systems that do not have adverse environmental impacts. This entails seeking answers to the question raised above. One step in the process is to classify agricultural systems according to some characteristics, and then explore the factors determining those systems (Ruthenberg, 1980; Pender et al., 2001; Koebrich et al., 2003). Accordingly, this study first classifies agricultural systems in the Chittagong Hill Tracts of Bangladesh based on several variables. This is followed by an analysis of factors influencing agricultural systems. Finally, policy conclusions are drawn for promoting environmentally and economically sound agricultural systems. This area was selected for study for two major reasons. First, it is the major mountain region of Bangladesh comprising several types of agricultural systems, ranging from shifting cultivation to commercial horticulture, despite similar topographical and climatic conditions (Rasul, 2003). Second, so far no effort has been made to examine the spatial pattern of agricultural systems in CHT and analyze their determinants using multivariate statistical techniques. In view of the increasing concern about environmentally and economically sound mountain agriculture, we hoped to learn useful lessons by analyzing the existing agricultural systems in CHT.

2. Why do agricultural systems vary from one place to another?

Researchers have been seeking an understanding of the variation in agricultural systems ever since the early 19th century when Ricardo (1887 in Bilsborrow and Carr, 2001; Mueller, 2003) examined variations in agricultural systems based on their intensity. Though Ricardo was not concerned about spatial patterns of agricultural systems, his contribution laid the foundation for many subsequent studies on agricultural systems. Von Thünen examined spatial arrangements of agricultural systems according to their distance to market centres (Symons, 1978; Visser, 1980). According to Von Thünen, agricultural intensity decreases with increasing distance to market, because it leads to reduced profit margins for farmers by incurring higher transportation costs. Although this explanation provided a basis for understanding spatial patterns of agriculture, it overlooked the role of biophysical, socioeconomic and institutional factors in facilitating the development of different types of agricultural systems. According to Blaikie (1971), where irrigated crops are grown, agricultural intensity is determined by the availability of water, rather than the distance to the market. The proponents of New Institutional Economics (such as Dorward et al., 1998; Kherallah and Kirsten, 2001) also consider availability of inputs as an important determinant of agricultural development.

Contributing to the on-going debate on evolution of agricultural systems, Boserup (1965) considered population density as a major factor influencing agricultural systems. Land scarcity arising from steadily growing population forces farmers to move gradually from extensive to intensive type of agricultural system, such as from forest fallow to annual cropping and from rotational to settled types of agricultural system. Several researchers (e.g., Ruthenberg, 1980; Pingali et al., 1987; Tiffen et al., 1994) have found positive associations between population growth and agricultural intensity. But others (e.g., Datoo, 1978; Grigg, 1979; Meertens et al., 1995) find Boserup's explanation too narrow, and argue that development of agricultural systems with different components and degrees of intensity is influenced by a range of several biophysical, socioeconomic and institutional factors.

Cultural ecologists such as Brookfield (1972), Turner II and Brush (1987) and Ali (1995) consider agricultural systems as a function of constraints imposed by the physical environment and the human capabilities to reduce and modify those constraints. They see people's adaptive capacities as a main source of agricultural innovation. However, they have not paid much attention to factors that determine human capabilities. According to Schultz (1964), traditional farmers will not be able to improve agricultural systems unless they have access to improved technologies, inputs, and markets. "Thrift and work are not enough to overcome the niggardliness of this [traditional] type of agriculture. To produce an abundance of farm products requires that the farmer has access to and has skill and knowledge to use what science knows about soils, plants, animals, and machines'' (Schultz, 1964, p. 205). For others such as Lipton (1968); Binswanger and McIntire (1987), knowledge and skill are essential, but not enough for adoption of improved type of agricultural systems. Despite being knowledgeable and skilled, poor shifting cultivators cannot apply the inputs required, such as improved seeds, inorganic fertilizers, and irrigation, because of poor institutional services or structural constraints imposed by institutions. Hayami and Ruttan (1971), Ramaswamy and Sanders (1992); Mcmillan et al. (1998) therefore, consider agricultural system development as a combined function of institutions and technology, because institutions not only govern the processes by which scientific and technical knowledge is created but also facilitate the application of new technology. Allan (1986), Turkelboom et al. (1996) and Reardon et al. (2001) emphasize the equally important role of infrastructure, including transportation facilities and access to market centres because they broaden the opportunities for the adoption of new technologies and crops. Availability of technology and infrastructure, access to market, and returns from agricultural enterprises are considerably influenced by national polices and laws (Sanders et al., 1996). Land tenure security and prices of agricultural products, which are shaped by national laws and agricultural policies, significantly influence farmers' profit margins and agricultural decisions (Ehui et al., 1995; Lele and Stone, 1989). Insecure land tenure not only act as a constraint to investment, but also deprives farmers of access to formal credit, inputs and other institutional services required for improved agricultural practices. As a result, farmers are often forced to continue traditional agricultural practices (Feder et al., 1988; Ehui et al., 1995; Li et al., 1998; Thapa, 1998; Rasul and Thapa, 2003; Rasul, 2003).

3. Materials and methods

3.1. Data sources

The field survey for this study was conducted in *Bandarban* district of CHT, located in the southeastern part of Bangladesh (Fig. 1), which is a typical district from the perspective of the agro-ecology and land use. The topography of the region is mountainous. About two-thirds of the area is characterized by steep to moderate slopes, ranging between 10° and 70°; the remaining area is gently sloping. The climate is sub-tropical, with a mean monthly maximum temperature ranging from 25 to 34 °C; the annual average rainfall ranges between 2032 and 3910 mm, 80% of which occurs during the period May to September.

The agricultural land in the study area is broadly divided into two categories, sloping lands and valley lands. Valley lands, classified as Class-I land, are suitable for all forms of cultivation. Gentle-sloping lands, classified as Class-II land, are suitable for terrace cultivation. Steeply sloping lands, Class-III land, are considered to be suitable only for non-arable land uses, such as forestry and horticulture (Roy, 1995). Valley lands cover only 6% of the region. The soils on the hill slopes are

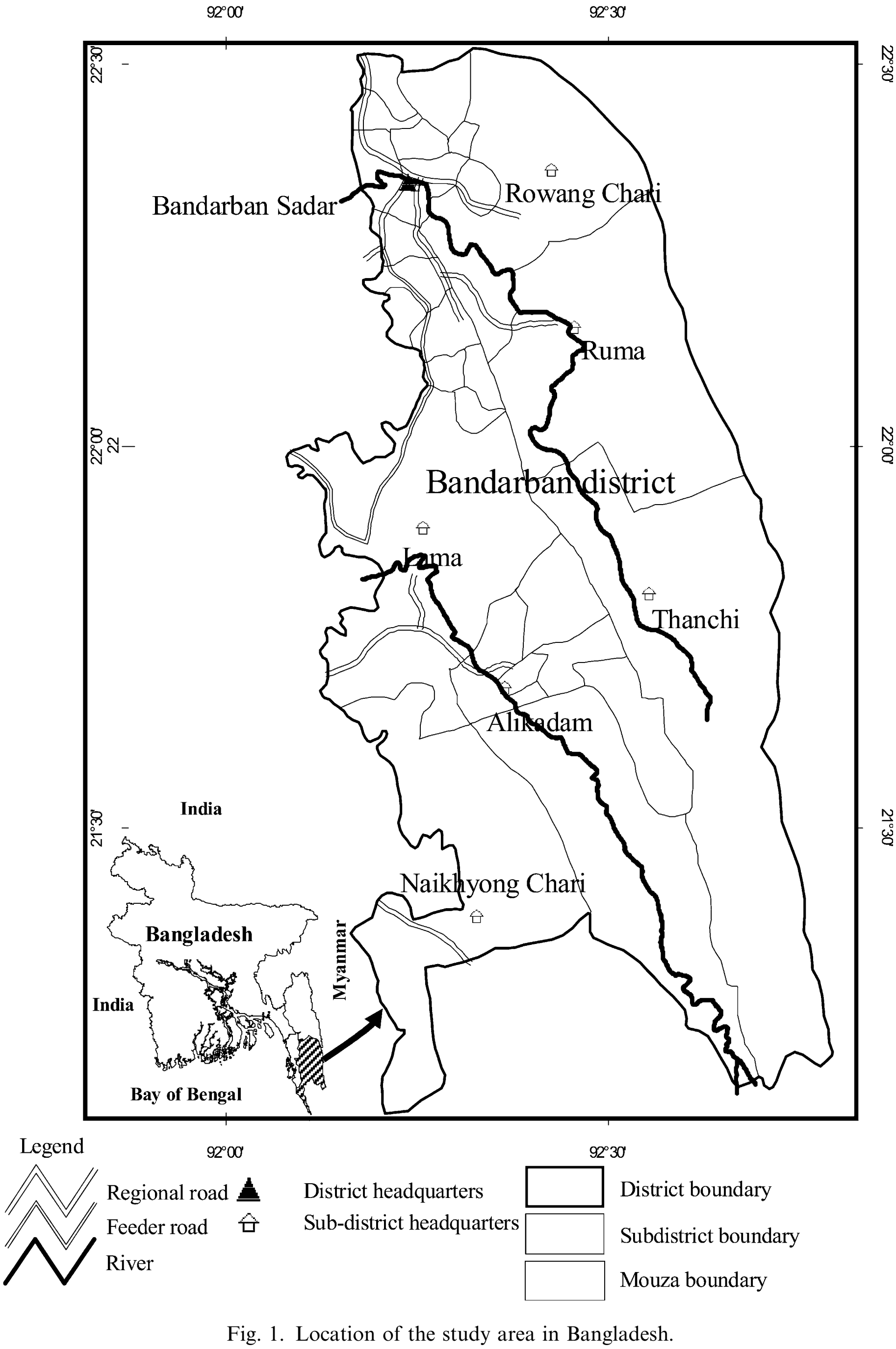

Fig. 1. Location of the study area in Bangladesh.

the dominantly brown loamy sands and silty clays; they are well-drained and strongly acidic. Normally these soils are deep, but shallow soils are found in areas with hard siltstone and sandstone. The nutrient status and moisture holding capacity are generally low. On the river terraces in the valleys, the soils are brown loams. Poorly drained gray silt and clay soils are concentrated in valley floors, and they are subject to seasonal flooding (Khan and Khisa, 2000).

There are 11 hill tribes in *Bandarban* district, comprising more than half of the total population. The other people are Bengalese, who have migrated into the area from the neighbouring plain region. *Marma* and *Mro* are the main tribal communities. The *Marma* normally live near streams and rivers; they are relatively better off in their socio-economic condition than the *Mro*. The *Mro* usually live at higher elevations; they are the most disadvantaged of the tribal groups in the area. *Bawm*, another tribal community, also live on the hill slopes. These three groups account for about 80% of the total tribal population of the district. Agriculture is the main source of livelihood of these people, who practise mainly shifting cultivation. The major crops cultivated under shifting cultivation are upland rice, maize, sweet potato, yam, vegetables, and spices such as chilly, turmeric, and ginger. The main cash crops are cotton and sesame. Non-farm income opportunities are very limited and in some areas non-existent.

3.2. Data collection methods

This study is based on both primary and secondary information collected from 36 villages of *Bandarban Sadar* and *Alikadam* sub-districts of *Bandarban* district. Consistent with its objectives of analyzing spatial patterns of agricultural systems and their determinants, this study uses the village as the analytical unit. Of the 36 randomly selected villages for the survey, 13 were from *Alikadam* and 23 from *Bandarban Sadar*. The villages vary in terms of land use, accessibility, access to support services and facilities, and ethnic composition. Data were collected both at village and household levels. Information on the founding of the village, distances to local markets and sub-district headquarters, time required to reach the road, existence of a school, soil types, major land uses, cropping patterns, educational facilities, and the presence or absence of NGOs or missions were collected at the village level through semi-structured interviews with village headmen, discussion with villagers, observations and key-informants interviews. Biophysical information, including the altitudes of the villages, was obtained from topographical maps. Information about the areas under agriculture, crops cultivated, livestock, income from off-farm activities, and the educational attainment of the villagers, was collected through a household survey. One third of the households from each village were selected randomly for the household survey. Lists of households were obtained from the village headmen who update the lists every year for land-tax collection. The questionnaire was pre-tested and revised. Information regarding their service delivery systems and area coverage was also obtained from government agencies, NGOs and missionaries working in the area. Information was collected from January to June 2002.

3.3. Data analysis methods

To achieve the objectives of this study, several statistical techniques were employed. The logical relationships between research objectives, analytical techniques, and result of the analyses are presented in Table 1. While analyzing agricultural systems, first 12 variables characterizing the systems were selected. The selected variables include proportion of area under shifting agriculture, horticulture, paddy cultivation, annual cash crops, average number of private trees per household, average number of fruit trees, average number of wood trees, and average number of cattle, pigs, goats, poultry, and proportion of produce used for household consumption, and they were used to identify the patterns of agriculture in the study area. The first column of Table 2 shows the variables used in the cluster analysis. Because of convenience in generating visual clustering, a hierarchical clustering method was used. The average linkages method of the cluster analysis with Pearson correlation was employed to generate clusters.

For the second stage, in order to explore the determinants of agricultural patterns predicted by cluster analysis, 16 variables reflecting village and household characteristics were selected. All variables except the following two are self-explanatory.

(i) Perceived land asset value (PLAV) was calculated based on the following formula

$$\mathrm{PLAV} = (h_{\mathrm{la}} * w_{i\ i=1\text{–}2} * s_{\mathrm{c}i\ I=1\text{–}4} * f_{\mathrm{c}i}) + (V_{\mathrm{la}} * w_i * sc * f_{\mathrm{c}i}),$$

where PLAV is the perceived land asset value; h_{la} is the sloping land area; v_{la} is the valley land area; and w_i (i = 1–2) is the weight for land types: hilly land = 1, valley land = 2 (these weights were given to land based on farmers' and experts' opinion). $s_{\mathrm{c}i}$ (i = 1–4) is the slope category: almost flat = 4, moderate slope = 3, steep slope = 2, and very steep slope = 1. $f_{\mathrm{c}i}$ (i = 1–3) is the soil fertility: good = 3, not so good = 2, poor = 1 (based on farmers' assessment).

Table 1
Relationships between research goals, statistical analyses and outputs

Research objectives	Statistical analyses	Output
To identify major agricultural systems based on multiple objective criteria	Cluster analysis	Three characteristically distinct agricultural systems: extensive, semi-extensive and intensive
To analyze relative influence of factors associated with agricultural systems	Factor analysis	Three explanatory factors, namely, institutional support, productive resources and distance to market and service centres predicted from 16 interrelated variables
	Discriminant analysis	The relative influence of factors in each type of agricultural system determined

Table 2
Main characteristics of the three patterns of agricultural systems in *Bandarban* district

Components of agricultural systems	Agricultural systems		
	Extensive $n^* = 18$	Semi-extensive $n = 15$	Intensive $n = 3$
Shifting cultivation			
Proportion of cropped area (%)	89	41	11
Mean area per HH (acre)	2.81 (0.93)	1.17 (0.33)	0.45 (0.11)
Horticulture			
Proportion of cropped area (%)	5	12	52
Mean area per HH (acre)	0.16 (0.16)	0.36 (0.12)	2.09 (0.59)
Paddy cultivation			
Proportion of cropped area (%)	4	29	–
Mean area per HH (acre)	0.20 (0.25)	1.08 (0.39)	0.01 (0.01)
Annual cash crops			
Proportion of cropped area (%)	2	5	12
Mean area per HH (acre)	0.06 (0.07)	0.19 (0.16)	0.46 (0.09)
Total trees			
Average number per HH	97 (107)	1805 (1283)	1348 (519)
Fruit trees			
Average number per HH	38 (62)	88 (104)	189 (27)
Wood trees			
Average number per HH	60 (84)	1717 (1214)	1159 (504)
Cattle			
Average number per HH	1 (0.83)	3.86 (2.03)	0.24 (.25)
Pigs			
Average number per HH	2.49 (1.82)	1.44 (1.04)	0.49 (.215)
Goats			
Average number per HH	0.28 (0.36)	1.67 (1.51)	0.41 (.34)
Poultry			
Average number per HH	7 (4)	15 (7)	9 (0.23)
Subsistence orientation			
Proportion of produce used for consumption by HH (%)	77 (7)	49 (8)	21 (4)

Note. n = number of villages; HH = household; SD = standard deviation; figures in parenthesis indicate standard deviation.

(ii) Education level is determined by the total number of years of schooling completed by all household members of school age and above, divided by the total number of members of the household of school age and above. This was deemed necessary as land-use decisions are often taken jointly by adult household

Table 3
Variables used in factor analysis and their statistics

	Mean	SD
Age of the settlement (year)	53.00	34.00
Availability of *jhum* land [a]	1.64	0.73
Elevation of the village (m above sea level)	196.00	64.00
Perceived land asset value (index value)[b]	10.00	4.00
Upland (%)	90.00	10.00
Proportion of households with land title deed (%)	45.00	41.00
Distance to the sub-district headquarters (in minutes)	93.00	34.00
Distance to the local market (in minutes)	79.00	38.00
Proportion of households, which had contact with extension agents (%)	17.00	22.00
Proportion of households, which had attended training (%)	12.00	21.00
Education level (index value)[b]	1.85	1.41
NGOs or missionaries working in the village[c]	0.31	0.46
Proportion of households who had obtained formal credit (%)	23.00	26.00
Proportion of households who had obtained informal credit (%)	30.00	33.00
Average off-farm income (Taka/household)	4040.00	4175.00
Proportion of households using external inputs (%)	5.69	3.92

[a] 3 = *jhumland* available, 2 = somehow available, 1 = not available.
[b] Index value derived through formula described earlier.
[c] 1 = NGOs or missionaries working in the village, 0 = NGOs or missionaries not working in the village.

members (Thapa and Weber, 1990; Pichon, 1997). The village education level was calculated by adding the years of schooling of sample households and dividing by the number of sample households of the respective village.

Agricultural land-use decisions are a complex, involving a large number of bio-physical, socio-economic and institutional factors. To identify the interrelationships between these variables and determine the basic patterns of those interrelationships, factor analysis was used. A total of 16 variables was used in the factor analysis. The descriptive statistics of these variables are presented in Table 3. The factor analysis extracted three principal factors, with eigenvalues more than one. These three factors explained 77% of the total variation. As our purpose was to use factor scores as input for further analysis, factors were rotated using orthogonal rotation (i.e., the varimax method) with Kaiser normalization, whereby the factors are independent of each other (Hair et al., 1992). The rotated factor matrix was examined and interpreted.

After identifying the factors influencing agricultural systems, the relative importance of each factor in determining the system was analyzed. Although the factor analysis transformed 16 variables into three composite variables or factors based on the respective factor score, the factor score could not explain the relative contribution of the factors in determining the patterns of agricultural systems. To see the relative importance of factors in determining agricultural systems we used the dependence method of analysis. Because here the dependent variables are categorical (three agricultural systems: extensive, semi-extensive and intensive), we used discriminant analysis following Yapa and Mayfield (1978) and Carter (1997). Although discriminant analysis is not as straightforward as regression analysis, it can explain the relative importance of the explanatory variables through its discriminatory coefficients (Hair et al., 1992; Tabachnick and Fidell, 1996). The magnitude of standardized discriminant coefficients shows the relative importance of explanatory variables on a particular discriminant function.

A discriminant function takes the following form:

$$d_{ik} = b_{0k} + b_{1k}x_{i1} + \cdots + b_{pk}x_{ip}, \quad (1)$$

where d_{ik} is the value of the kth discriminant function for the ith case; p is the number of explanatory variables; bjk is the value of the jth coefficient of the kth function; and xij is the value of the ith case of the jth explanatory variable.

The standardized b values show the relative contribution of each explanatory variable to the discriminant function, which is analogous to the β coefficients in multiple regression (Cooley and Lohnes, 1971; Yapa and Mayfield, 1978; Tabachnick and Fidell, 1996).

Although a standardized discriminant coefficient explains the extent to which an explanatory variable contributes to the discriciminant function, it cannot explain the relative importance of explanatory variables across functions. To examine the relative importance of individual explanatory variables, we calculated the potency index for each explanatory variable, based on the standardized discriminant coefficient method developed by Hair et al. (1992, 108–109).

4. Agricultural systems in Bandarban district

The cluster analysis employed to identify the types of agricultural systems in *Bandarban* district generated a range of solutions (Fig. 2). Looking at different solutions and possible cutting points, one can see that at cutting point 'A' two clusters are formed, with agricultural patterns 2 and 3 combined into one cluster. At cutting point 'B', three clusters are formed, with 18 members in cluster I, 15 in Cluster II, and 3 in cluster III. If we go for more than three clusters, for example, at cutting point 'C', one case (village 5) is separated from cluster I. In cluster II, two cases (village 22 and 23) could not be classified. If we go further, the pattern of clustering becomes less clear. After examination of different solutions and possible cutting points, the three clusters associated with point B was found to be realistic and we accepted this as a meaningful classification. The validity of the classification was tested using discriminant analysis (Aldenderfer and Blashfield, 1984), which shows that 97% of the cases were classified correctly. The cluster analysis classified the agriculture systems of 36 villages of the study area into three types, which are named extensive, semi-extensive and intensive [1] (Fig. 2) based on their essential characteristics. The following paragraphs briefly describe those.

[1] Agricultural intensity may be considered from two perspectives; one is frequency of cultivation per unit area (Boserup, 1965; Ruthenberg, 1980) and the other is the intensity of input use, i.e., labour and capital on per unit of land to increase productivity (Brookfield, 1972). In this paper, we considered agricultural intensity as the proportion of area under shifting cultivation. The lower the proportion of area under shifting cultivation, the higher the agricultural intensity.

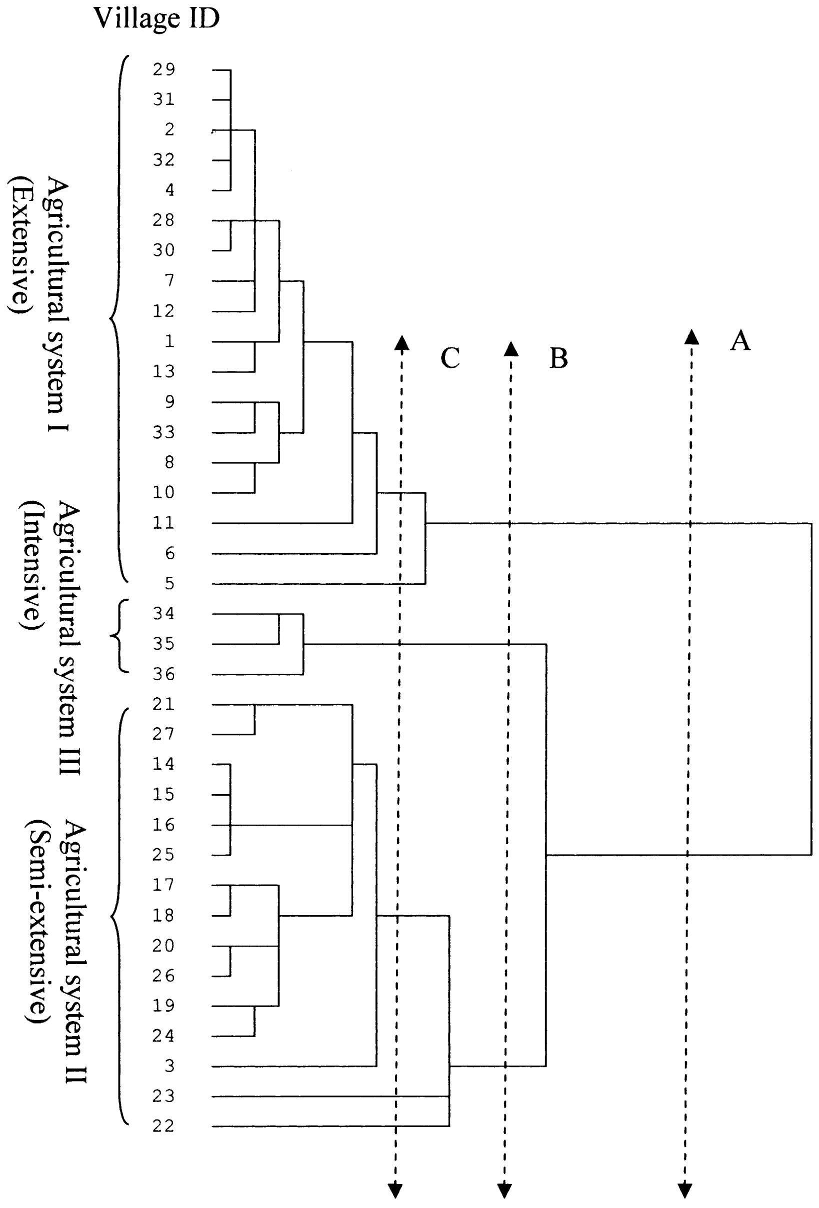

Fig. 2. Dendrogram showing clusters of 36 villages into three types of agricultural systems.

4.1. Agricultural system 1: extensive agriculture

Traditional shifting agriculture (*jhum*) has been widely practised for a long time in large parts of *Alikadam* and in the remote areas of *Bandarban Sadar*, without much change. Production is mainly consumption oriented. All *Mro* and about one-third of the *Marma* farmers are engaged in this type of agriculture. Farmers change cultivated plots almost every year to maintain soil fertility. Normally they keep a plot fallow for 3–4 years depending on the availability of land. Food crops such as rice, maize, and vegetables dominate the cropping systems. Because of poor road conditions and distances of the villages to roads and markets, horticultural and annual cash crops, and paddy cultivation are insignificant (Table 2). Fruits and horticultural crops are grown mainly for home consumption; local varieties of cotton and oilseeds are grown in some areas. Livestock products and tree crops are also mainly for household consumption. The methods of cultivation remain traditional. Every year, the farmers clear a new parcel of land using the traditional slash-and-burn method. Bush knife, axe and digging stick are the main agricultural implements. No specific soil-fertility measures are practised, except for keeping the land fallow for a few years after harvest. Off-farm income opportunities are scarce and forest products, mainly bamboo and wood, are the major supplementary sources of income.

4.2. Agricultural system II: semi-extensive agriculture

In the lower-altitude areas with flat land and river terraces, which are located adjacent to the plains of Chittagong district, annual cropping has been adopted to a certain extent along with shifting cultivation, and livestock and tree crops are integrated into the farming system (Table 2). The majority of the *Marmas* practise this type of agriculture. Although shifting cultivation occupies two-thirds of the cultivated area, annual crops, agroforestry and livestock are equally important components. The farmers use livestock for draught power as well as for a source of cash income. The methods of cultivation have changed considerably over time; the plough is used for land preparation in flat areas, and irrigation is practised wherever possible by constructing weirs across the streams. The valley lands are cultivated intensively; sometimes two or three crops are grown in a year. Traditional intercropping practices have been replaced by mono-culture of rice and wheat. Cash crops such as potato and vegetables are cultivated near the roadsides. On hill slopes, tree crops and agroforestry occupy many former *jhum* plots. Shifting cultivation still occupies a considerable proportion of the sloping land.

4.3. Agricultural system III: intensive agriculture

In some areas, particularly near the roadsides in *Bandarban* Sadar, agriculture has changed remarkably, from cereal-based subsistence agriculture to fully market-oriented commercial agriculture, with intensive use of sloping land. This type of agriculture is practised mainly by *Bawms* who have settled in the higher-altitudes areas along the *Bandarban–Chimbuk* road. The area under shifting cultivation is negligible, accounting for only about 10% of the total agricultural land (Table 2). Traditional crops such as rice, maize, and vegetables have been replaced by high-value cash crops such as pineapple, banana, papaya and other fruits. Tree crops are grown in association with annual and perennial crops. Agroforestry is also an important component of the system, but livestock insignificant. The farmers' land-management practices have changed considerably and now include mulching, strip cropping and rotational cropping together with the use of organic and inorganic fertilizers to maintain soil fertility.

5. Determinants of agricultural systems in Bandarban district

The factor analysis extracted three factors (Table 4) from 16 explanatory variables initially identified (see Table 3) with eigenvalues greater than one. These three factors explained 77% of the total variance. Most variables, except 'land title', 'informal credit', and 'education level', were loaded unambiguously in the three factors. These variables carried high loadings in both the first and the second factors, but slightly higher loadings in the first factor. All variables except 'extension service' and 'age of settlement', have factor loadings with an absolute value greater than 0.5, indicating that a significant percentage of the variance of each variable is explained by these three factors.

More than half of the variables carried high loadings in the first factor, which explained about 44% of the total variance. Variables with high loadings are 'attendance of training', 'formal credit', 'external inputs', 'presence of NGOs/missionaries' and 'land title' (Table 4). The high negative loading of 'informal credit' separates this variable from other variables clustered in this factor. As all variables included in this factor are somehow associated with support services, this factor is referred to as 'institutional support'.

Table 4
Rotated factor matrix (for explanation, see text)

Variables	Factors		
	1	2	3
Proportion of households which had attended training	.898		
Proportion of households which had obtained formal credit	.850		
Proportion of households using external inputs	.798		
NGOs/missionaries working in the village	.698		
Proportion of households with land title deed	.669	.646	
Proportion of households who had obtained informal credit	−.666	−.567	
Education level	.620	.561	
Perceived land asset value	.538	.651	
Proportion of households which had contacts with extension agents	.537		
Upland		−.855	
Average off-farm income		.748	
Age of the settlement		.554	
Distance to the local markets			.883
Distance to the sub-district headquarters			.874
Elevation of the village		−.575	.669
Availability of *jhum* land	−.561		.573

The second factor explained about 20% of the variance, including about half of the variables. 'Perceived land asset value', 'Upland' and 'off-farm income' carried strong loadings, i.e., above 0.72, followed by 'land title' and 'age of settlements' (Table 4). The strong negative loading of the variable 'upland' separates this variable from others included in this factor. As most variables are related to land and other income sources, this factor is referred to as 'productive resources'.

The third factor explained about 13% of the variance. Four variables, i.e., 'distance to sub-district headquarters', 'distance to local markets', 'elevation' and 'availability of *jhumland*' included in this factor carried loadings above 0.62 (Table 4). This factor is named 'distance to the market and service centre', as most variables are associated with distance to the market and sub-district head quarters where service centres are located.

5.1. Relative importance of the factors influencing the patterns of agriculture

A discriminant analysis employed on the three composite variables namely 'institutional support', 'productive resources', and 'distance to the market and service centre' as determinants of the dependent variable ''agricultural systems'', generated two discriminant functions. Both functions were significant at 1% level ($p < 0.001$). The first function accounted for 65% and second function 35% of the variability between the three different types of agricultural systems, with eigenvalues of 6.26 and 3.32, respectively.

Cannonical correlations between the explanatory variables and the standardized canonical discriminant functions show that the variable 'institutional support' has the strongest absolute correlation with function 1, and 'productive resources' has the largest absolute correlation with function 2. The variable 'distance to market and service centre' has a small association with both functions (Table 6). Following Klecka (1980, 31–32), the first function is characterized as institutional support and the second is productive resources.

Fig. 3 shows that the three types of agricultural systems are quite distinct; their centroids and mean values of the discriminant score are well separated and there is not much overlap of individual cases. The first discriminant function separated the extensive type of agricultural system from semi-extensive and intensive types, and the second discriminant function separated the semi-extensive type from intensive and extensive types of agricultural systems. This indicates that different types of agricultural systems have differential access to institutional support and productive resources. Intensive and semi-extensive types of systems have received significantly higher 'institutional support' than extensive types of system. The semi-extensive system has access to a relatively higher degree of 'productive resources' than the intensive and extensive systems. This is also reflected in the classification function coefficients, which show the relationship between explanatory variables and agricultural systems (Table 5).

The standardized discriminating coefficients, which show the relative importance of explanatory variables on the discriminant function (Klecka, 1980; Tabachnick and Fidell, 1996), show that on function 1, two explanatory variables, 'institutional

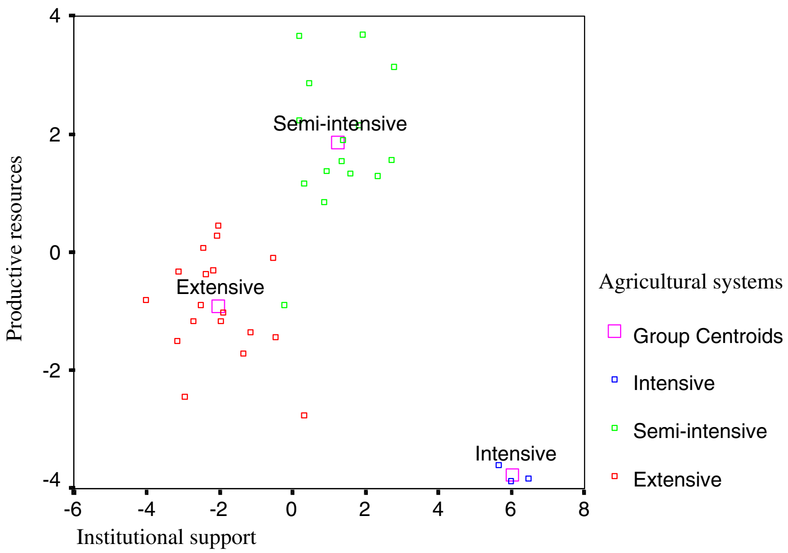

Fig. 3. Scatter plot of group centroids of three types of agricultural systems.

Table 5
Relationship between explanatory variables and agricultural systems (for explanation, see text)

Explanatory variables	Agricultural systems		
	Extensive	Semi-extensive	Intensive
Institutional support	−4.692	2.239	16.962
Productive resources	−2.708	4.094	−4.222
Distance to market and service centres	1.563	−1.662	−1.070
Constant	*−3.187*	*−3.366*	*−27.764*

support' and 'distance to market and service centre' carried a significant score (as per Hair et al., 1992, a score above 0.3 is significant). On function 2, 'productive resources' and 'distance to the market and service centre' carried significant scores. The latter variable has a moderate weight on both functions. Therefore, all three explanatory variables have significant influence in shaping the agricultural systems. However, the magnitude of the discriminant score of the individual variables, which indicates the relative role of the explanatory variables in determining the scores on the function (Klecka, 1980; Hair et al., 1992), shows that 'institutional support' had a relatively higher contribution to function 1, followed by 'distance to the market and service centre' (Table 6) and 'productive resources' has a relatively higher contribution on function 2, followed by 'distance to the market and service centre'. The potency index, which is an indicator of the relative importance of individual variables across functions, reveals that 'institutional support' has the largest contribution to shaping land-use systems, followed by 'productive resources' and 'distance to the market and service centre' (Table 6).

Table 6
Discriminant function coefficients and potency index

Explanatory variables	Correlation*		Standardized discriminating score		Potency index
	Functions		Functions		
	1	2	1	2	
Institutional support	0.897**	−0.282	1.034	−0.193	0.711
Productive resources	0.124	0.819**	0.270	1.065	0.441
Distance to market and service centre	−0.077	−0.137	−0.511	−0.538	0.270

* Pooled within-group corrections between explanatory variables and standardized canonical discriminant functions.
** Largest absolute correlation between each explanatory variable and discriminant functions.

6. Conclusions and policy implications

In the Chittagong Hill Tracts of Bangladesh, where shifting agriculture used to be the only type of agricultural systems until the mid-20th century (Lewin, 1869), several types of agricultural systems have developed in different locations. The cluster analysis employed to classify these different systems revealed three major patterns: extensive, semi-extensive and intensive, according to intensity of land use. The extensive agricultural system, dominated by shifting cultivation, is still practised in the majority of areas. This system is characterized by cultivation of assorted crops for subsistence requirements, with a short fallow period of 2–3 years. External implements and inputs are rarely used. The semi-extensive system is characterized by intensive land preparation using a plough and application of external inputs such as irrigation water and inorganic fertilizers to enhance yield. Part of the land is used for annual crops integrated with livestock and trees. While cereals are produced for household consumption, some non-cereal crops, livestock, and livestock and tree products are sold for cash income. The intensive agricultural system is fully commercialized, with horticulture, animal husbandry, and plantation as major components. Well linked to external markets, such as agricultural system can be financially and environmentally superior to other agricultural systems (ADB, 2001; Rasul, 2003), that has so far developed in few locations.

The question arises as to why in different locations of a small district of CHT, with similar topographical features and climatic conditions, three different types of agricultural systems have developed. The extensive system, dominated by shifting cultivation with a short fallow period, is both environmentally and financially unsuitable compared with other semi-extensive and intensive systems. Why does a majority of farmers still practise such agricultural system? No satisfactory answer to this question can be observed based on Boserup's explanation by itself, which considers population growth as a stimulating factor for agricultural development (Boserup, 1965). Population has grown steadily in all districts of CHT during the last decades, and this has to some extent compelled shifting cultivators to shorten the fallow period from 10–12 years during the 1950s to 3–4 years at present. However, semi-extensive and intensive agricultural systems could develop only in selected areas. Findings of the analysis suggest that in the face of growing land scarcity owing to a growing population, the productive resource base of the people, the institutional support available to them, and access to the market have all played important roles in the development of different types of agricultural systems in the study area. This conclusion is corroborated by findings of studies conducted in the northern Thailand (Rerkasem and Rerkasem, 1994; Turkelboom et al., 1996) and Sub-Saharan Africa (Pingali et al., 1987). Intensive agricultural systems, characterized by high-value cash crops that do not require frequent hoeing and ploughing of lands, could develop only in a few areas where farmers had acquired permanent land title, and were provided with access to the necessary inputs and technical assistance by an NGO. In addition, access to market centres provided by all-weather roads has been another important factor facilitating the development of such agricultural systems. Horticulture and tree-crop-based intensive agricultural systems require investment of labour and financial resources, but can provide positive returns after several years. Farmers are not likely to adopt such systems without secure ownership or usufruct rights to land.

In the majority of areas, farmers were still practising an extensive agricultural system dominated by shifting cultivation, which requires investment of labour but provides little return. Farmers were well aware of the advantages of more intensive agricultural system. Still they could not adopt semi-extensive and intensive type of agricultural systems primarily because of lack of secure land rights, which not only deters investment in agricultural development (Feder et al., 1988) but also deprives farmers of access to the credit required to buy inputs and implements. Moreover, farmers had no access to institutional support services and facilities, nor to appropriate market centres.

A semi-extensive agricultural system, comprising a blend of shifting cultivation, livestock husbandry, annual crops, agroforestry and tree crops, has been adopted by farmers in those areas endowed with higher quality resources such as lowlands with irrigation water, and access to some support services and facilities. However, a majority of farmers was still practising shifting cultivation in upland plots without any kind of ownership or usufruct right. Some of the semi-extensive farmers, with some kind of land title or usufruct rights, could not practise intensive commercial agriculture because of difficult access to market centres and rudimentary extension services and credit facilities. These findings are in contrast to the arguments of cultural ecologists such as Sopher (1963), Khan and Khisha (1970) and Ali (1995) who see physical environment and resource base as the major determinants of agricultural systems. Our findings clearly show that even within similar biophysical environments and with similar resource bases, different types of agricultural system may develop depending on land tenure security, level of institutional support, mode and condition of agricultural infrastructure, and accessibility to market centres.

The findings of this study have important policy implications for promotion of environmentally sustainable and economically viable mountain agricultural systems in Bangladesh and elsewhere. As discussed in the introduction, mountain regions are confronted with problems of deforestation, land degradation and poverty, partly because of shifting cultivation and cereal-crop-based sedentary agricultural systems. As long as such agricultural systems continue to be practised, it is difficult to see how mountain people can improve their quality of life and control land degradation (Thapa, 1996). In order to enable them to secure higher income in a sustainable way, it is essential to promote agricultural systems that are environmentally suitable as well as economically attractive. Findings of empirical studies conducted in the Chittagong Hill Tracts (Rasul, 2003) and in the hills of Nepal (Pandit, 2003) have shown that agroforestry comprising commercially valuable tree species, fruit farming and livestock husbandry are economically far more attractive than the traditional agricultural systems, provided that institutional hurdles such as agricultural levies and taxes are removed. Such agricultural systems are also conducive to controlling soil erosion and landslides as they do not require tillage practices.

Moving from extensive to semi-extensive or intensive agriculture systems requires substantial amounts of investment of labour and financial resources. In some instances, as in the case of some tree crops, farmers start getting returns after several years. Farmers cannot be expected to make such investment, which may require them to obtain credit at high interest rates, without secure rights to land. Provision of extension services and credit alone cannot motivate farmers to make investments when they are under the constant threat of eviction. Provision of secure land title or usufruct rights to land is indispensable for any effort geared at promoting economically and environmentally sustainable systems. Mountain farmers in Nepal would not have adopted terraced farming without inheritable land rights (Rasul and Thapa, 2003). However, this provision alone would not enable farmers to adopt semi-extensive or intensive agricultural systems, as they may not have the technical knowledge required about locationally suitable and economically attractive agricultural systems. In addition, they do not have the capital required for investment. Inheritable land rights were provided to farmers who had settled in government-initiated resettlement schemes, with the aim of promoting sedentary agricultural systems. But because of the lack of extension services and credit facilities, most resettlers have abandoned lands allocated to them and are actively engaged in shifting cultivation (Rasul, 2003). Thus, as suggested by Hayami and Ruttan (1971), there is a need to make provision for effective institutional support, including extension services and credit to enable farmers to adopt their preferred agricultural system. Farmers make investments in order to increase returns from agricultural enterprises. This can happen only when they have access to market centres and can get fair prices for their products. This entails linking areas with extensive and semi-extensive agricultural systems with market centres by developing infrastructure such as roads. Secure land title and good support services provided to farmers in some areas of CHT would not alone have facilitated development of intensive agriculture, if these areas had not been provided with access to market centres. Therefore, a comprehensive strategy is required for promoting environmentally compatible and economically attractive agricultural systems in CHT and elsewhere. Such a strategy should focus on the provision of secure land tenure, effective institutional support services, and good road infrastructure.

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References

ADB (Asian Development Bank), 2001. Chittagong Hill Tracts region development plan. Final Report, ADB TA No. 3328, Rangamati.

Aldenderfer, M.S., Blashfield, R.K., 1984. Cluster analysis. Sage University Papers Series: Quantitative Applications in the Social Sciences. Sara Miller McCune, Sage Publications.

Alegre, J.C., Cassel, D.K., 1996. Dynamics of soil physical properties under alternative systems to slash-and-burn. Agriculture, Ecosystem and Environment 58, 39–48.

Ali, A.M.S., 1995. Population pressure, environmental constraints and agricultural changes in Bangladesh: examples from three agroecosystems. Agriculture Ecosystems Environment 55, 95–109.

Allan, N.J.R., 1986. Accessibility and altitudinal zonation models of mountains. Mountain Research and Development 6, 11–18.

Baker, R., 1984. Protecting the environment against the poor. Ecologist 14, 53–60.

BCEOM/SEATEC/SEMED, 1999. Nam Ngum watershed management. Draft Final Report, Ministry of Agriculture and Forestry, Vientiane, Laos.

Bilsborrow, R.E., Carr, D.L., 2001. Population, agricultural land use and the environment in developing countries. In: Lee, Lee, D.R., Barrett, C.B. (Eds.), Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment. CABI Publishing, Wallingford, UK.

Binswanger, H.P., McIntire, J., 1987. Behavior and material determinants of production relations in land abundant tropical agriculture. Economic Development and Cultural Change 36, 73–99.

Blaikie, P.M., 1971. Spatial organization of agriculture in some north Indian villages: part II. Transactions of the Institute of British Geographers 53, 15–30.

Boserup, E., 1965. The Conditions of Agricultural Growth: the Economics of Agrarian Change under Population Pressure. Earthscan Publications, London.

Brookfield, H.C., 1972. Intensification and disintensification in Pacific agriculture: a theoretical approach. Pacific Viewpoint 13, 30–48.

Carson, B., 1992. The land, the farmer and the future: a soil fertility management strategy for Nepal. ICIMOD Occasional Paper No. 21. International Center for Integrated Mountain Development, Kathmandu.

Carter, S.E., 1997. Spatial stratification of Western Kenya as a basis for research on soil fertility management. Agricultural systems 55, 45–70.

Charlton, C.A., 1987. Problems and prospects for sustainable agricultural systems in the humid tropics. Applied Geography 7, 153–174.

Chazee, L., 1994. Shifting practices in Laos: present system and their future. Report of the Nabong Technical Meeting, Vientine, Laos.

Cooley, W.W., Lohnes, P.R., 1971. Multivariate Data Analysis. Wiley, New York.

Datoo, B.A., 1978. Toward a reformulation of Boserup's theory of agricultural change. Economic Geography 54, 135–143.

Dorward, A., Kydd, J., Poutton, C., 1998. Smallholder Cash Crop Production under Market Liberalization: a New Institutional Economics Perspective. CAB International, Wallingford, UK.

Douglas, M., 1999. IFAD proposed program for Asia: a strategy for alleviation of poverty through sustainable development in the uplands of Asia. A Paper Presented at the Workshop on Special

Programs for Sustainable Upland Development in Asia – Reality Check Consultation, 19–21 April, 1999, Klong Luang, Thailand, Organized by IFAD/IUCN.

Ehui, S., Williams, T., Swallow, B., 1995. Economic factors and polices encouraging environmental detrimental land use practices in sub-Saharan Africa. Agriculture competitiveness: market forces and policy choice. In: Proceedings of the 22nd International Conference of Agricultural Economists, Harare, Zimbabwe, 22–29 August 1994, pp. 444–463.

Feder, G., Onchan, T., Chalamwong, Y., 1988. Land policies and farm performance in Thailand's forest reserve areas. Economic Development and Cultural Change 36, 483–501.

Gafur, A., 2001. Effects of shifting cultivation on soil properties, erosion, nutrient depletion and hydrological responses in small watershed of the Chittagong Hill Tracts of Bangladesh. Doctoral dissertation, The Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Grigg, D.B., 1979. Easter Boserup's theory of agrarian change: a critical review. Progress in Human Geography 3, 64–84.

Hair Jr, J.F, Anderson, R.E., Tatham, R.L., Black, W.C., 1992. Multivariate Data Analysis: With Readings. Macmillan Publishing Company, New York pp. 87–136.

Hayami, Y., Ruttan, V.W., 1971. Agricultural Development: An International Perspective. The Johns Hopkins University Press, Baltimore.

Holscher, D., Ludwig, B., Moller, R.F., Folster, H., 1997. Dynamics of soil chemical parameters in shifting agriculture in Eastern Amazon. Agriculture, Ecosystems and Environment 66, 153–163.

Ives, J.D., 1985. The mountain malaise: quest for an integrated development. In: Sing, T.V., Kaur, J. (Eds.), Himalayan Books. Himalayan Books, New Delhi.

Juo, A.S.R., Manu, A., 1996. Chemical dynamics in slash-and-burn agriculture. Agriculture, Ecosystems and Environment 58, 49–60.

Khan, F.K., Khisha, A.L., 1970. Shifting Cultivation in East Pakistan. The Oriental Geographer 14, 24–43.

Khan, N.A., Khisa, S.K., 2000. Sustainable Land Management with Rubber –Based Agroforestry: A Bangladeshi Example of Uplands Community Development. Sustainable Development 8, 1–10.

Kherallah, M., Kirsten, J., 2001. The new institutional economics: applications for agricultural policy research in developing countries. MSSD Discussion Paper No. 41, International Food Policy Research Institute, Washington, DC.

Klecka, W.R., 1980. Discriminant analysis. Sage University Papers Series No: Quantitative Applications in the Social Sciences, 07-001. Sage Publications, Beverly Hills and London.

Knudsen, J.L., Khan, N.A., 2002. An exploration of the problems and prospects of integrated watershed development in the CHT. In: Khan, N.A., Alam, M.K., Khisa, S.K., Millat-e-Mustafa M. (Eds.), Farming Practices and Sustainable Development in the Chittagong Hill Tracts, CHTDB and VFFP-IC, Chittagong, pp. 165–180.

Koebrich, C., Rehman, T., Khan, M., 2003. Typification of farming systems for constructing representative farm models: two illustrations of the application of multi-variate analyses in Chile and Pakistan. Agricultural Systems 79, 141–157.

Lele, U., Stone, S., 1989. Population pressure, the environment and agricultural intensification: variations on the Boserup hypothesis. Managing Agricultural Development in Africa, Discussion Paper 4, World Bank, Washington, DC.

Lewin, T.H., 1869. The Hill Tracts of Chittagong and the Dwellers Therein, with Comparative Vocabularies of the Hill Dialects. Bengal Printing Company, Calcutta.

Li., G., Rozelle, S., Brandt, L., 1998. Tenure, land rights, and farmer investment incentives in China. Agricultural Economics 19, 63–71.

Lipton, M., 1968. The theory of the optimizing peasant. Journal of Development Studies 4, 327–351.

Mcmillan, D.E., Sanders, J.H., Koenig, D., Akwabi-ameyaw, K., Painter, T.M., 1998. New land is not enough: agricultural performance of new lands settlement in West Africa. World Development 26, 187–211.

Meertens, H.C.C., Ndege, L.J., Enserink, H.J., 1995. Dynamics in Farming Systems: Changes in Time and Space in Sukumaland, Tanzania. Royal Tropical Institute, Amsterdam, Netherlands.

Mueller, D., 2003. Land-use Change in the Central Highlands of Vietnam: A spatial econometric model combining satellite imagery and village survey data. Ph.D. dissertation. George – August-University of Goettingen, Germany.

Neupane, R., Thapa, G.B., 2001. Impact of the agroforestry intervention on soil fertility and farm income under the subsistence farming system of the middle hills, Nepal. Agriculture, Ecosystems and Environment 84, 157–167.

Pandit, B.H., 2003. Prospects of non-timber forest products promotion in the mountains of Nepal. Ph.D. Dissertation, Asian Institute of Technology, Thailand.

Pender, J., Scherr, S.J., Duron, G., 2001. Pathways of development in the Hillside areas of Honduras: causes of implications for agricultural production, poverty and sustainable resource use. In: Lee, D.R., Barrett, C.B. (Eds.), Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment. CABI Publishing, Wallingford, UK.

Pichon, F.J., 1997. Settler households and land-use patterns in the Amazon frontier: farm-level evidence from Ecuador. World Development 25, 67–91.

Pingali, P., Bigot, T., Binswanger, P.H., 1987. Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa. A World Bank Publication. Johns Hopkins University Press, Baltimore pp. 216.

Ramaswamy, S., Sanders, J.H., 1992. Population pressure, land degradation and sustainable agricultural technologies in the Sahel. Agricultural Systems 40, 361–378.

Rasul, G., 2003. Factors influencing land-use change in areas with shifting cultivation in the Chittagong Hill Tracts of Bangladesh. Ph.D. Dissertation, Asian Institute of Technology, Thailand.

Rasul, G., Thapa, G.B., 2003. Shifting cultivation in the mountains of South and Southeast Asia: regional patterns and factors influencing the change. Land Degradation and Development 14, 495–508.

Reardon, T., Barrett, C.B., Kelly, V., Savadogo, K., 2001. In: Lee, D.R., Barrett, C.B. (Eds.), Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment. CABI Publishing, Wallingford, UK.

Rerkasem, K., Rerkasem, B., 1994. Shifting cultivation in Thailand: its current situation and dynamics in the context of highland development. IIED Forestry and Land Use Series No. 4, 3 Endsleigh Street, London, p. 108.

Roy, R.D., 1995. Land Rights, Land Use and Indigenous People in the Chittagong Hill Tracts. In: Gain, P. (Ed.), Bangladesh Land Forest and Forest People. Society for Environment and Human Development (SEHD), Dhaka, Bangladesh.

Ruthenberg, H., 1980. Farming Systems in the Tropics, second ed. Clarendon Press, Oxford.

Sanchez, P.A., 1994. Alternative to slash and burn: A pragmatic approach for mitigating tropical deforestation. In: Anddrson, J.R. (Ed.), Agricultural technology: policy issues for the international community. CAB International, Wallingford, pp. 451–479.

Sanders, J.H., Shapiro, B.I., Ramaswamy, S., 1996. The Economics of Agricultural Technology in Semiarid sub-Saharan Africa. The John Hopkins University Press, Baltimore and London.

Schultz, T.W., 1964. Transforming Traditional Agriculture. Yale University Press, New Haven.

Sopher, D.E., 1963. Population dislocation in the Chittagong Hills. The Geographical Review 3, 338–361.

Symons, L., 1978. Agricultural Geography, third ed. Bell and Hyman Limited, London pp. 187–223.

Tabachnick, B.G., Fidell, L.S., 1996. Using Multivariate Statistics. Harper Collins College Publishers, New York.

Thapa, G.B., 1998. Issues in the conservation and management of forests in Laos: the case of Sangthong District. Singapore Journal of Tropical Geography 19, 51–70.

Thapa, G.B., 1996. Land use, land management and environment in a subsistence mountain economy in Nepal. Agriculture, Ecosystems and Environment 57, 57–71.

Thapa, G.B., Paudel, G.S., 2000. Evaluation of the livestock carrying capacity of land resources in the hills of Nepal based on total digestive nutrient analysis. Agriculture, Ecosystems and Environment 78, 223–235.

Thapa, G.B., Weber, K.E., 1990. Managing Mountain Watershed in Nepal: The Upper Pokhra Valley Nepal. HSD Monograph No. 22, AIT, Bangkok, Thailand.

Tiffen, M., Mortimore, M., Gichuki, F., 1994. More People, Less Erosion: Environmental Recovery in Kenya. John Wiley & Sons, West Sussex, England.

Turkelboom, F., Van, K.K., Ongprasert, S., Sutigoolabud, P., Pelletier, J., 1996. The changing landscape of the Northern Thai hills: adaptive strategies to increasing land pressure. Montane Mainland Southeast Asia in Transition. Chiang Mai University, Thailand.

Turner II, B.L., Brush, S.B., 1987. Comparative Farming Systems. The Guildford Press, New York.

Uddin, M.S., Kamal, M.S., Mollah, M.H., 2000. Hill Farming System and Resource Utilization in Chittagong Hill Tracts. Hill Agricultural Research Station, Khagrachari pp. 1–64.

Visser, S., 1980. Technological change and the spatial structure of agriculture. Economic Geography 56, 311–319.

Yapa, L.S., Mayfield, R.C., 1978. Non-adoptions of innovations: evidence from discriminant analysis. Economic Geography 54, 145–156.