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CHARM Project Report 4

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Chittagong Hill Tracts Improved Natural Resources Management

Bangladesh






Land Management Practices in the Chittagong Hill Tracts and Sustainable Alternatives

CHARM Project Report 4

LAND MANAGEMENT PRACTICES IN THE CHITTAGONG HILL TRACTS AND SUSTAINABLE ALTERNATIVES

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1. Introduction

The total area of the Chittagong Hill Tracts (CHT) is about 1,329,500 ha (BCAS, 2006) (1,320,106 ha according to the Statistical Year Book, cited by HARS, 2000), of which 53,500 ha are occupied by settlements and water bodies.

In administrative terms, and according to ADB (2001), some 710,000 ha, called 'Unclassified State Forests', are under the control of the Ministry of Land. A further 332,500 ha have the official status of 'Reserve and Protected Forests' and are under the control of the Forest Department. Finally, private planted forests occupy 57,000 ha. Land tenure and administration is one of the main socio-economic problems in the CHT (Roy, 2002; Adnan, 2004).

5.5 people living in each household. This implies that there are some 200,000 rural households in CHT. This population is nowadays roughly equally distributed between the Bengali and the Jummas (general term that includes the various hill ethnic groups, Chakma, Marma, Tripura, Mro, and Tanchangya being the main ones).

The survey by BCAS (2006) of 463 households in the three districts of the CHT shows that about 33% of the population is engaged in either *Jhum* or plainland farming or horticulture. Similarly, the results obtained by Mallick (2001a) show a 35% of the population as self-employed in agriculture. This population engaged in agriculture or related activities obtain 62% of the household income (Rashid, 1995).

Table 1 Land use in the CHT (ha) (HARS, 2000)

	1970	1980	1990
Total area	1,303,808	1,303,808	1,303,808
Forest	1,201,048	1,174,082	818,800
Net cropped area	63,352	47,069	85,600
- single crop	32,192	47,689	57,200
- double crop	27,920	20,580	22,400
- triple crop	3,240	2,800	6,000

The distribution of the main land uses in the CHT is shown in Table 1. The term 'forest' in this table may include very different ecosystems, because natural undisturbed forests in Sangu and Matamuhuri Reserve Forests, for example, where their proportion may be expected to be highest within the CHT, just occupy 12% of the area, while other forests represent a further 64% (Salam *et al.*, 1999). The data presented by these authors for the Kassalong and Rainkhiong Reserve Forests similarly show that timber forests only occupy 18% of these reserves while mixed timber-bamboo stands represent a further 19%.

The population of the CHT is about 1,342,795 (BCAS, 2006), of which some 81% lives in rural areas (Rafi and Nath, 2001), with a mean number of

The size of households in the CHT is very uneven, with a large mass of very small and functionally landless holdings. The proportion of landless households varies between 20% in the Bengali ethnic group, 15% among the Chakma, 7-8% within the Marma and Tripura, and less than 0.5% among the Mro.

The data from BCAS (2006) show a 9.3% of households with a total size of less than 0.2 ha, but the survey by Mallick (2001a) produces higher figures, with 32-42% of households of that size among the Bengali, Marma, Mro, and Tripura, but only 8% among the Chakma.

The 1983/84 land statistics show the following distribution of holdings in the CHT according to size (Ahmed and Rahman, 1995):

- households with at least 3 ha: 8% of households, occupy 28% of the land,
- households with 1 ha to 3 ha: 48% of households, occupy 58% of land,
- households with 0.02 ha to 1 ha: 44% of households, occupy 14% of land.

These results are very similar to those obtained by BCAS (2006) in their survey for the CHARM Project.

A much more extensive survey of 2550 households by BRAC (Mallick, 2001a) shows that 68-84% of households own less than 2 ha of land, and that the average amount of land owned varies between 0.56 ha and 1.28 ha across the various ethnic groups.

The data obtained in the same survey (Mallick, 2001b) shows that, in terms of food security, households that break even (not necessarily by producing themselves all their food needs) use a minimum of about 1.04 ha of cultivated land. Households producing themselves a sufficient amount of staple crop to meet household demand throughout the year is only 32% of total households, according to BCAS (2006).

Agricultural production is therefore mostly based on subsistence systems. The local shifting cultivation system, called *jhum*, is the main agricultural land use, but is also a way of life connected to many other aspects of human existence (Borgaard *et al.*, 2003; Mey, 2005). The decrease in the length of the fallow period of *jhum*, as a result of the increase in population in the CHT, has raised much debate about the sustainability of the system.

Plainland plough agriculture was not introduced in the CHT until 1860, and even in the 1950s 'cultivation is negligible and is found only in a few places in the valleys' (Johnson and Ahmad, 1957, cited in Mey, 1978). Since the 1950s, governments have introduced, in various resettlement or development projects, alternative land use systems, such as fruit and rubber plantations and spatial agroforestry systems (Khan and Khisa, 2000; Khisa, 2001; Paul and Emdad Hossain, 2001; Nath *et al.*, 2005).

2. Objectives

According to the terms of reference set for this work package (see section 1), the objectives of our work were:

- to review the existing literature on the land use systems of the Chittagong Hill Tracts (CHT) and other areas similar in terms of soil, climate, or socio-economic conditions,
- to update and complement existing information on the main land use systems of the CHT, with particular emphasis on their inputs and outputs, in order to detect any problems in relation to their sustainability,
- to identify options that may increase the sustainability of land use systems in the CHT.

3. Materials and Methods

A review of literature on the CHT, its agriculture, forestry, and land use problems, and on land use practices in areas similar to the CHT in terms of climate, soil and/or land use was undertaken. The most relevant references have been incorporated in this report and in the database produced.

Forty farms were surveyed across the three CHT districts, 16 in Rangamati, 16 in Bandarban, and 8 in Khagrachuri. The smaller number in Khagrachuri was due to time constraints. Two criteria were used to select the interviewed farmers:

- some farmers were randomly chosen in villages where traditional land uses (*jhum*, plainland and fringeland agriculture) are undertaken,
- farmers trying alternative crops were specifically targeted.

A semi-structured questionnaire was prepared touching upon issues of household characteristics (number of members, age and education), land owned and used, income from farm and outside activities, general natural resource issues and perceptions, and area, inputs and outputs involved in the various plots of land used. Estimates of manure available per household were calculated from data on animals in each household and manure availability according to Tian-ren (1989).

At the same time, some specific fields within the farms were visited to describe some aspects such as slope, soil cover, and soil erosion features. Rates of soil erosion were estimated from plot features following Stocking and Murnaghan (2001).

Sustainability of land-use systems was analysed at a plot scale. Simple mass-balance budgets were estimated for soil mass based on data from the literature. Outputs considered were those from soil erosion for the different land-use systems and inputs those from rock weathering (Alexander, 1985; Minasny and McBratney, 1999). The results of the soil mass budget were used to estimate the soil life if the same land-use system was constantly applied through time.

Land suitability for some selected fruit species was evaluated on the basis of existing soil and climate data as compiled in the CHARM Information System, and using the Plantgro software (Ye and Hutchinson, 2005), with further inputs from farmers' perceptions obtained during the field survey and data from the literature.

4. Results

4.1. Households

The households surveyed have a mean size of 3 ha in terms of land owned (varying from 0 ha to 18 ha), and of 3'5 ha in terms of land used (varying from 0.16 ha to 18 ha). In this respect our survey is biased towards the bigger households, which should be taken into account when interpreting the results. Still, 28% of our households use less than 1.2 ha.

In both groups there is a positive correlation between income from land resources and income from outside the farm (for full-time farmers $r = 0.79$, $p < 0.005$; for part-time farmers $r = 0.53$, $p < 0.05$), therefore showing another division, this time between farms with a rather self-sufficient economy on the one hand, and farms with a predominantly-cash economy on the other.

Table 2. Land ownership and use according to the main source of income of the surveyed farms

Mean area (ha)	Full-time farms	Part-time farms
total land owned	2.22	3.82
total land used	2.81	4.08
homestead	0.12	0.10
fruit garden	0.36	0.60
jhum	0.40	0.18
ploughland	0.42	0.25
rubber garden	0	0.66
wood plantation	1.32	1.96
fringe land	0.09	0.12

There is a clear polarization between farms that obtain more than 50% of their income from farm produce, hereafter called full-time farms, and those that obtain less, hereafter called part-time farms (see Table 2).

Full-time farmers own and use less land than part-time farmers, and the proportion of land the former own in relation to the land they use (79%) is smaller in comparison to that of the latter (94%).

Furthermore, full-time farmers use larger amounts of ploughland and jhum, and therefore they have a larger degree of self-sufficiency in terms of staple crop production (the equivalent to 8.5 months of consumption compared to 7.1 months equivalent).

On the other hand, part-time farmers devote more land to horticulture, rubber, and wood plantations. The latter two occupy 64% of the land these farmers use, and all three land-use types involve 80% of this land.

Households that produce themselves enough staple crop to satisfy their needs throughout the year use over 1.7 ha, mostly with more than 1.0 ha of cultivated land, which is in agreement with the data presented by Mallick (2001b).

4.2. Land Use Systems and Products

4.2.1. Ploughland

Production system

Ploughland basically occupies valley bottoms, river banks and lower slopes in the CHT. In agreement with the data provided by HARS (2000), only about 7% of the ploughland produces 3 crops per year, while some 25% produces 2 crops, and 68% produces 1 crop per year. The main crops are rice (*Oryza sativa*), vegetables, sugarcane (*Saccharum officinarum*), and potatoes (*Solanum tuberosum*).

Tobacco (*Nicotiana tabacum*) is very frequent on the sandy river terraces in the area around Ruma.

This is the land use system that concentrates the biggest amount of inputs in the CHT. Only 10% of the surveyed plots do not use synthetic fertilizers and only 20% do not use any pesticides.

Manure is only explicitly used in less than 15% of plots, at rates between 800-1200 kg/ha, but animals may graze the plots during fallow periods in the dry season.

Urea is applied in more than 80% of cases in amounts varying between 10-400 kg/ha for vegetables and rice, and 310-2500 kg/ha for sugarcane. Triple superphosphate (TSP) and muriate of potash (MP) are applied in 70% of cases. Rates of application of TSP are 150-310 kg/ha for vegetables and rice and 310-3750 kg/ha for sugarcane, while for MP the rates are 40-125 kg/ha for vegetables and rice and 75-1250 kg/ha for sugarcane.

Rice production varies mostly between 1100-1600 kg/ha for *aus* rice and 2000-3000 kg/ha for *aman* and *boro* rice, which is in agreement with figures provided by HARS (2000), and is partially related to urea application at the rates used (Figure 1).

Sustainability issues

The content of topsoil organic matter in ploughlands in Bangladesh has decreased by 20-46% in the past 20 years, thus becoming one of the main causes of low productivity in this land use system (Zahid Hossain, 2001). While no actual data seems to be available specifically for the CHT, the reasons for this processs may be related to the unfrequent use of manures or compost.

The use of synthetic fertilizers seems quite unbalanced in many cases because only urea is applied. This may also result in a decrease in soil organic matter due to increased mineralization (Manna *et al.*, 2006).

Furthermore, both urea and muriate of potash (MP) are acidifying fertilizers, the effect of which may need to be countered by the application of liming materials if available.

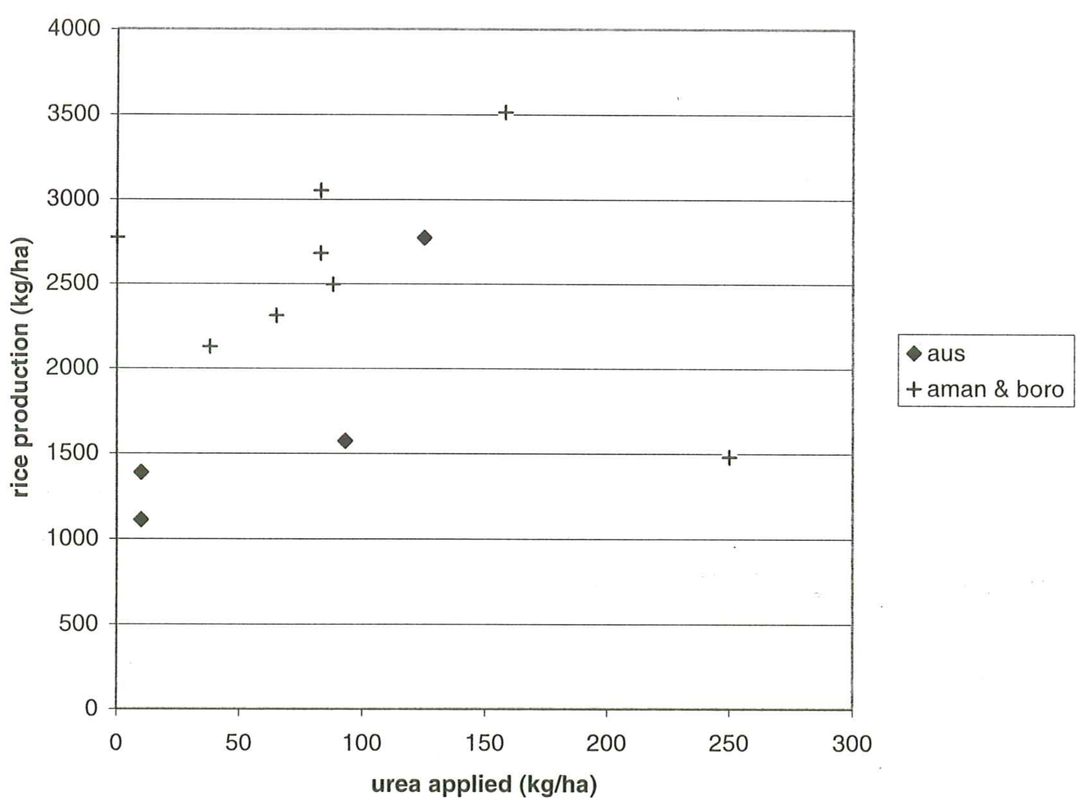

Figure 1. Rice production in ploughland according to season and urea application in the surveyed fields.

Alternative pesticides should be used instead of some of the very dangerous ones presently used like parathion, dieldrin, diazinon, mancozeb, malathion, and furadan.

4.2.2. *Jhum*

Production system

Jhum is practised on slopes up to 45° steeper slopes not being considered suitable. The most frequent cycle involves 1 year cropping and 4-5 years fallow which agrees with the results obtained by Khan (2004). The longest fallow recorded is 7 years, while this author has also found some cases of cycles of up to 25-30 years.

For the cropping year, a continuous plot is slashed and burned, more or less regardless of the variability in the conditions within the plot. Therefore, if some gullies or small areas with slopes steeper than 45° are within the *jhum* plot, they will also be slashed and burned, even though they may not be seeded afterwards.

Jhum is an intercrop of many species, but the most frequent are rice, turmeric (*Curcuma longa*), marfa (*Cucumis melo*), chilli (*Capsicum annum*), and ginger (*Zingiber officinalis*), although many others are less frequently intercropped. Ginger and turmeric are sometimes also produced as monocrops. Banana (*Musa spp.)* and other fruits and wood tree species may be kept within the *jhum* plot and fruits collected even after the cropping year, during the first fallow years. Stems of banana plants may also be kept from fire and piled so as to produce mushrooms during the cropping year.

Use of external inputs is less frequent in jhum than in ploughland. Pesticides are used in about 60% of jhums and in almost 70% there is some input of synthetic fertilizers, but only in 8% of the cases manure is applied.

Manure is applied at rates of up to 1000 kg/ha. Urea is applied in 70% of cases at rates of up to 940 kg/ha, but TSP and MP are only applied in 20-25% of cases at rates of up to 310 kg/ha and 250 kg/ha respectively.

Rice production is mostly in the range of 1,000-2,000 kg/ha (Figure 2), but with a wide range of variation, that may be related to the diversity in

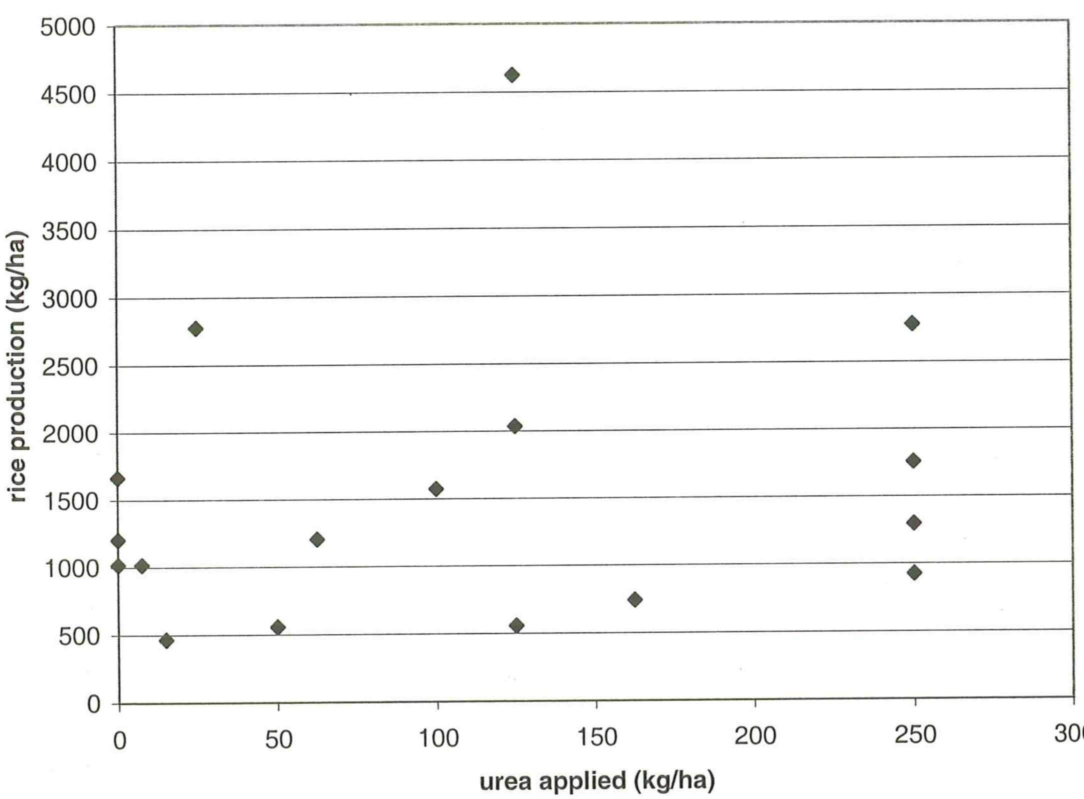

Figure 2. Rice production in jhum according to urea application in the surveyed fields.

environmental conditions, intercropping patterns, and fallow periods. It should be noticed that in some plots in which no fertilizer is used yields are still in the order of 1,000-1,500 kg/ha.

Furthermore, rice production in jhum is quite similar to that obtained in ploughland considering that in jhum various other species are also grown. Total vegetable production in jhum varies between 60-3,500 kg/ha.

Production of ginger and turmeric when planted as monocrops or as mixtures of the two varies between 700-1,000 kg/ha when no synthetic fertilizer is applied and 5,000-14,000 kg/ha with fertilizer application.

Total crop production in jhum varies, therefore, between 700-15,000 kg/ha (Figure 3), with relatively high levels (6,000-9,000 kg/ha) in some jhums that are receiving no fertilizers. It is clear from Figure 3 that there is no apparent relation between yield and amount of fertilizers applied, which, again, may be due to the variation in fallow periods, environmental conditions, and intercrop mixtures.

Sustainability issues

Most farmers acknowledge a 50% <u>decline in productivity</u> of jhum land during the past 10-12 years, which has also been suggested by Khisa (1998). According to data from the late 19th century (Lewin, 1869; Hutchison, 1906, both cited by Rasul *et al.*, 2003), rice production in jhum was then about 1500 kg/ha. Present yields are similar (see previous section), but with the added expense of pesticides and synthetic fertilizers.

The present fallow period of less than 5 years, with bushes and tall grasses, is not sufficient for all soil properties to recover (Lam *et al.*, 2005). With this short jhum cycle of 4-5 years, succession is arrested

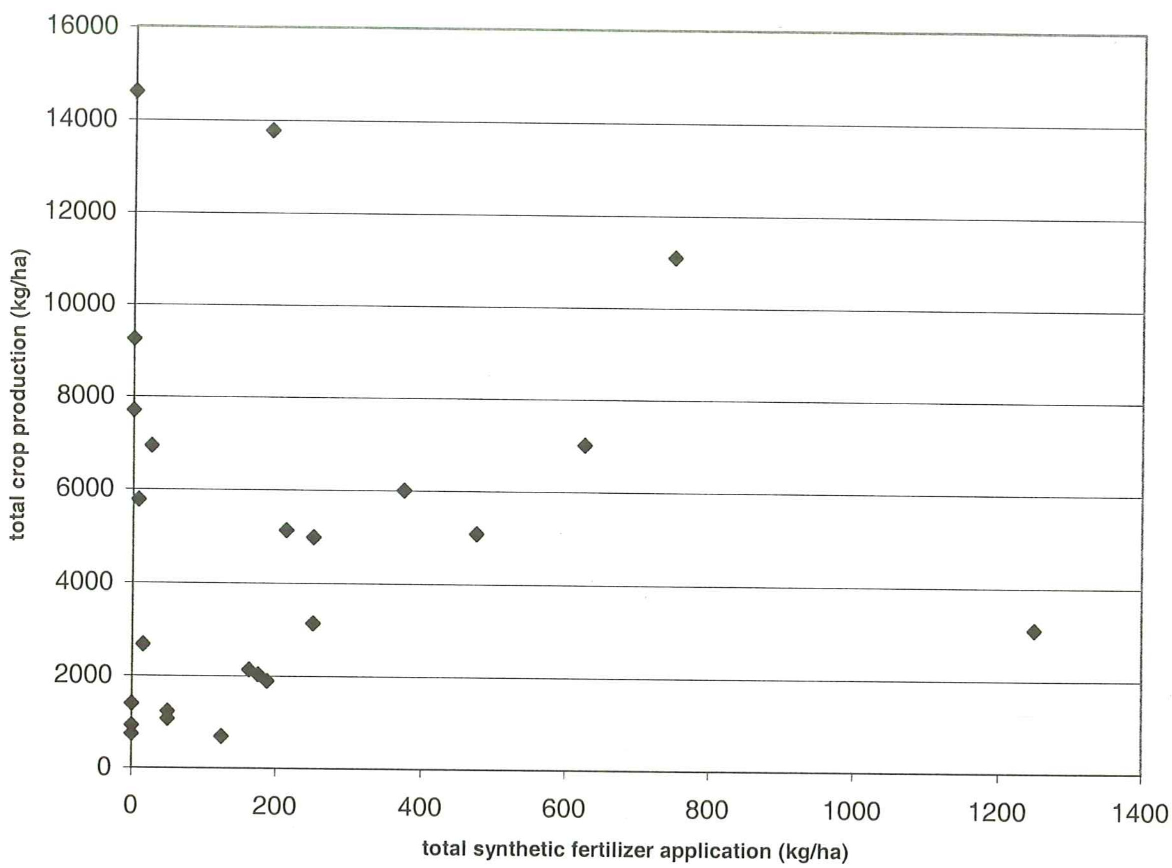

Figure 3. Total crop production (rice, vegetables and ginger and/or turmeric) in surveyed jhums in relation to total synthetic fertilizer application

at a stage of low biomass and litterfall production and quick mineralization of organic matter due to the open conditions.

Soil water erosion (which results in a decrease in soil water holding capacity and organic matter and nutrient content) is most probably the main process involved in the decline of productivity in jhum land. Rates of soil erosion in jhum plots range from 1-120 t/ha/yr in the cropping year to 1-12 t/ha/yr in years 4-10 of the fallow period (Ramakrishnan, 1992; Roder *et al.*, 1995a; Khisa, 2001; Rahman *et al.*, 2001; Hoang Fagerström *et al.*, 2002; Gafur *et al.*, 2003, 2004; Lam *et al.*, 2005).

With the present cycle of 1 year cropping plus 4-5 years of fallow, a mean annual rate of erosion is in the order of 20-30 t/ha/yr. This implies that a soil 30 cm deep would erode in 100-200 years of continuous 5 year jhum-cycles, while a soil 60 cm deep would take 200-400 years to erode.

The process of soil organic matter decline in jhum fields may be related not only to short fallows and erosion but also to unbalanced use of synthetic fertilizers. In the case of jhum, the use of urea only is much higher than in ploughlands, therefore contributing to increased mineralization of organic matter.

Other issues related to jhum include soil acidification (Bhuiyan, 2000), which is partly related to the application of urea, and the effects of which on crop production are magnified by the decreasing soil organic matter levels. As in the case of ploughland, some dangerous pesticides are also used: malathion, mancozeb and dichlorvos. And a problem specific to jhum is the frequent spread of fire to neighbouring plots when burning slash.

Conservation practices

During our survey we recorded very few specific techniques of soil conservation for jhum:

- In some cases farmers were using mulches for turmeric and ginger. But some other farmers, when questioned about this practice, answered that they would not use it for fear of excess moisture damaging the tubers, which has also been suggested by Uddin (1995).
- In other cases in ginger-turmeric plots, farmers were digging small trenches (20-30 cm deep, 40-50 cm wide) every 15-20 m across the slope to divert runoff water.

4.2.3. Fringeland

Production system

Fringeland occupies some 9,000 ha (ADB, 2001) of river terraces and valley bottoms influenced by the changing water level around Lake Kaptai.

This land is used for monocrop rice in the March-July season. While pesticides were applied in all cases encountered during our survey, manure was never applied. Urea was applied in 60% of cases, but TSP and MP were never applied.

Rates of urea application are mostly in the range of 40-65 kg/ha, and in this case the reported yields are 1100-1800 kg/ha. With no application of urea, yields are in the range of 700-925 kg/ha. Yield were reported to be lost 1 every 3 years due to unexpected changes in the water levels.

Sustainability issues

The circumstantial nature of fringeland surely involves a limited management. Nevertheless, the same issues discussed for ploughland are applicable, but most particularly the use of dangerous pesticides due to the proximity to Lake Kaptai and therefore to the fishing activities and water sources for many people.

4.2.4. Fruit gardens

Production system

These plantations mostly occupy slopes up to 35° and in the case of pineapple even up to 40°.

Only 50% of the households surveyed had a specific fruit garden (althoug they may have scattered fruit trees in the homestead or in jhum plots), and households with sizeable fruit gardens (those over 0.4 ha) only represent 35% of all households surveyed. The latter are using in all over 1.6 ha of land and/or have other important sources of income from outside the household. Holdings of this size may represent less than 25% of the holdings in the CHT, according to the data from Mallick (2001 a).

The survey by Rasul *et al.* (2004) similarly showed that only 8% of their surveyed households in the Bandarban and Alikadam districts had significant amounts of land devoted to horticulture, and that the adoption of this land use system was related among other factors to the presence of a government settlement program and to availability of off-farm income and other productive resources.

In every case recorded in our survey these gardens bear a mixture of various species, mostly pineapple (*Ananas comosus*), mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), litchi (*Litchi chinensis*), and jolpai (*Elaeocarpus robustus*), and sometimes including species for wood production like gamari (*Gmelina arborea*).

Pesticides are used in 55% of the cases recorded and synthetic fertilizers in about 80%. Manure is used in 25% of them but only for some specific species, like orange and mango, and at rates of 0.1-1 kg/tree. Urea is used very frequently in 80% of cases at rates of up to 1100 kg/ha, TSP in less than 40% of cases at rates of up to 600 kg/ha and MP in 30% of plots at rates of up to 75 kg/ha.

Plant density in these gardens is quite variable. Density of monocrop pineapple varies in the range of 18,000-60,000 plants/ha. Higher densities are reported to give higher quality and sweeter fruits.

When mixed with fruit trees, pineapple density is 600-6,000 plants/ha and that of trees is 250-1300 trees/ha. When fruit trees are planted without pineapple, density is in the range 550-2500 trees/ha.

Many of the plantations surveyed are still young and it is therefore difficult to provide meaningful estimates of their yields.

Sustainability issues

Plots with fruit trees visited during the surveyed showed a good ground cover of grasses and litter, with little apparent soil erosion. Gafur *et al.* (2003) recorded erosion rates of 4-10 t/ha /yr, which means that it would take some 400 years for a 30 cm-deep soil to erode completely. The litter from grasses and mulches may also help maintain the organic matter content of soils.

All plots with pineapple plantations that were visited during the survey had the rows along the contour but soil erosion features were more obvious, particularly during the first year of the plantation and if the distance between rows is 1 m or more. With closer spacings and older plantations the eroded soil seems to be stopped by the next row of pineapples. Our field estimates indicate rates of soil erosion up to 80 t/ha/yr, while Paul and Emdad Hossain (2001) have recorded erosion rates of 24 t/ha/yr. Assuming a mean rate implies that a 30 cm-deep soil would take about 100 years to erode.

But in pineapple plantations the very low cover of weeds, which are simply disposed off and the lack of application of manures or mulches would indicate a trend towards decreasing levels of organic matter in soils and increasing susceptibility to erosion.

Unbalanced fertilization practices, once again through the sole use of urea would also push towards lower organic matter content in soils and increase soil acidification rates.

Some dangerous pesticides, such as Furadan and Dichlorvos are also used in these fruit gardens.

Conservation practices

One case was reported of a farmer planting bamboo on the lower edge of his pineapple plantation close to Lake Kaptai in order to control mass movements on the slope.

4.2.5. Rubber plantations

Production system

Although the number of households with rubber (*Hevea brasiliensis*) gardens that were interviewed was very small, these seem to fall under two circumstances: either settlers from some government program or large households with other sources of income from outside.

These plantations are usually weeded twice a year for the first years. In most cases, fertilizers (urea, TSP, and MP) are applied at a rate of 100-200 kg/ha.

Sustainability issues

Rubber plantations cannot be automatically considered as beneficial for soils just because they are tree plantations. Soil erosion rates can be high (37 t/ha/yr according to Cha *et al.*, 2005, possibly in the first years of the plantation) and processes of organic matter and nutrient depletion and soil acidification have been described in them (Zhang and Zhang, 2005).

4.2.6. Wood plantations

Production system

Plantations recorded occupy slopes up to 45º and are mostly a mixture of teak (*Tectona grandis*) and gamari (*Gmelina arborea*). Adoption of these plantations is quite widespread (60% of surveyed households) and almost 90% of households with plantations have over 0.4 ha with this land use system. When not mixed with fruit trees, the density is very high, 2500-11200 trees/ha.

Quite frequently farmers are planting teak and gamari in jhum plots instead of leaving them under fallow. One of the reasons produced by the farmers is that in this way their tenure on the plot is asserted, whereas if it was left fallow many of them argue that the Forestry Department may take it away from them. This argument has also been found in Laos (Roder *et al.*, 1995b). Frequently farmers believe that this land use is also a form of soil conservation.

After planting, these plots are usually weeded by hand during the first 3 years and afterwards by setting fire to the undergrowth in the case of teak plantations. In only one case was urea applied to the plantation at a rate of 50 kg/ha.

Gamari trees are cut at the age of 10-12 years, while teak needs 20-30 years. In both cases the trees resprout from the stump and this practice may be repeated up to 3-5 times.

Teak plantations are also very frequent in Forest Reserves and account for 70% of the plantations raised following clearcutting, which is the main method of management by the Forest Department (Salam *et al.*, 1999; Adnan, 2004). Ahmed (2006) estimates that some 95,000 ha in the CHT are now used for this species. The expansion of both teak plantations and clearcutting methods seems to be related to the strong emphasis made on both by the Forestal Report of 1966.

Sustainability issues

Teak and gamari plantations show very obvious features of intense soil water erosion, with field-estimated rates of 60-270 t/ha/yr that are consistent with those found in the literature. As early as in 1973, Bell recorded soil erosion rates of 10-150 t/ha/yr in 9-11 year-old teak plantations in Trinidad. In Indonesia, Purwanto and Soerjono (1989) measured rates of 34 t/ha/yr. Such rates of erosion will lead to the complete degradation of most soils in the short-term (less than a century).

The reasons for this high rates of erosion are related to:

- The almost complete absence of ground vegetation (Amponsah and Meyer, 2000; Kolmert, 2001; Kraenzel *et al.*, 2003), which in turn may be related to the high density of trees in these plantations, to the dense shade of the trees and to the use of fire for weeding. This would also push towards low levels of organic matter in the soil.
- Rain drops falling from the leaves of these trees are much greater than for other species with smaller leaves, therefore contributing to smaller rainfall interception (Calder, 2001).

Furthermore, these issues would also lead to high surface runoff in these plantations (Bandara and Somasiri, 1992) which would result in increased peak-flows and decreased base-flows in the catchment. The high density of trees may also lead to increased consumption of water.

Harvesting of teak plantations also exports large amounts of basic cations and calcium in particular may become a limiting factor for production in the very-short term (Bruijnzeel, 1992; Chandrashekara, 1996; Amponsah and Meyer, 2000).

Teak litter decomposes very quickly which coupled with the use of fire for weeding and the relatively small production of roots, may result in insignificant additions of organic carbon to soil (Sankaran, 1993; Kraenzel *et al.*, 2003).

Conservation practices

One case was recorded in which lines along the contours had been built with slash prior to plantation with teak. The effectiveness of this practice could not be assessed but may help in reducing soil erosion rates.

4.2.7. Homestead

Production system

The area immediately around the house up to 0.4 ha but mostly 0.1-0.2 ha, is used as an intercrop of fruit trees and various vegetables.

Irrigation is applied in over 30% of surveyed homesteads, while in about 50% pesticides, synthetic fertilizers (mostly only urea) and manure are also applied.

Production is mostly destined for self-consumption and harvested irregularly, and though considered to be very important for the household economy it was very difficult to record yields.

Sustainability issues

Some very dangerous chemicals are used in homesteads among them malathion, parathion, and furadan.

4.2.8. Domestic animals

Production system

Some 60% of the surveyed households were recorded to have some domestic animals. Birds (hens and ducks) are present in most cases, 50% of all households, in numbers up to 70, while pigs (1-13 per household), goats (1-15 per household), and milk cows (2-6 per household) are each present in 20-30% of households. The number of animals per household has apparently decreased in time due to the decrease in the land available.

Most animals range freely around the villages, goats and cattle graze the lower lands during the fallow period in the dry season and the most frequently used supplementary foodstuff is rice wastage.

The amount of manure theoretically available in the households varies between 20 kg/yr and 70,000 kg/yr for those that have animals. Applying this manure only to plots with ploughland, jhum and fruit trees would represent rates of 17 kg/ha/yr to 75,000 kg/ha/yr (but mostly 5,000-20,000 kg/ha/yr).

These figures contrast sharply with actual manure applications, therefore suggesting that most of the manure is not managed due to the free ranging system and that there is some scope for improvement in this respect.

4.2.9. Wild products

Production system

Most households (70%) collect some amount of wild products. Fuelwood is the main item with each involved household collecting 600-8000 kg/year. Mature bamboo, specially when the houses need repairing and bamboo shoots are the other most frequently collected products. But many other game and plant species are obtained from private or public forests and make an important contribution to the household economy.

4.3. Land Suitability for Selected Crops

The suitability of some selected crops in the various soil units and climatic conditions of the CHT is shown in Annex 1. These results should be taken with caution, as a first approximation to the issue. In particular, the degree of limitation should be taken as a relative number rather than an absolute figure. It should also be taken into account that, for almost every single species, there are different varieties some of which may be able to grow and produce in environmental conditions quite different to those that can stand the other varieties of the same species. This may be specially true for local varieties some of which may have not even been identified.

Furthermore, the lack of climatic data at high altitude in the CHT, e.g. at 500-600 m, does not allow a proper assessment of suitability at this altitude. Nevertheless, we have provided some guidelines on the basis of other literature and farmers' opinions.

These results stress some issues that have already discussed:

- the use of synthetic fertilizers should be balanced because at present it gives little emphasis to phosphorus and potassium in comparison to nitrogen. Phosphorus, in particular stands out as a very important limitation.

- soil acidity should be considered specially in soils that may have become strongly acid and for some sensitive crops such as ginger, which has an optimum pH between 5.7 and 6.5 (Nybe and Raj, 2004), and for most *Citrus* species, litchu and papaya, that will suffer at pH below 5. The search for some liming material will become an important issue.

5. Discussion and Suggestions

We will now discuss the main issues in relation to the possibilities for improvement of land use in the CHT. In the first place, those that have a general scope or may be applicable to most or all of the land-use systems and then those that are specific for each. At the end of this chapter Table 1 summarizes the main points.

5.1. General Issues

Land availability

As we have already discussed, the amount of cultivated land needed by a household in the CHT to have a minimum food security is 1.04 ha (0.64 ha of jhum plus 0.40 ha of ploughland) and considering a 5-year fallow a further 3.20 ha of fallow land would be needed. All in all adds to a minimum of 4.24 ha of land per household. Assuming a total of 200,000 households in the CHT the total amount of land needed would be about 848,000 ha, or 64% of the total area of the CHT.

Following those figures, in a given year about 10% of the CHT would be used for jhum, a total of 16% would be cultivated and 48% would be under fallow.

Tress do not guarantee soil conservation

It is a recurrent theme in many reports (e.g., ADB, 2001) and even among farmers, as we have previously discussed, that simply by planting trees in a plot soil erosion will stop and soil properties will improve. It is also implicit in such statement that the contrary is also true, i.e., that land uses without trees are not able to control soil erosion or improve soil properties.

Both statements are oversimplifications, and the case of teak/gamari plantations in the CHT (see section 4.2.6) is very much an obvious example, as is also possibly the case of rubber plantations, particularly during the first years. Tea plantations have also been suggested as an alternative but they may have severe problems of soil degradation as well (Stocking, 1993; Yu *et al.*, 2004; Zhang and Zhang, 2005).

Increase the collection and use of organic materials

We believe that all land-use systems in the CHT are facing an organic matter crisis due to the very low amounts of these materials used and the high mineralization rates expected in these systems. While more specific issues for some land-use systems will be discussed later on, there are some general practices that are applicable to all of them:

- weeds should not be simply thrown away but collected and used for mulching and/or composting.
- balanced use of synthetic fertilizers. Do not rely on urea alone but use TSP and MP too,
- collect household wastes for composting,
- collect manure from domestic animals as much as possible.

Manage to slow down soil acidification

Soil acidification is another process undermining the soil resources of Bangladesh (Bhuiyan, 2000; Rahman *et al.*, 2001). It is partially a natural process in these very wet climates but its rate is intensified by some management practices. Synthetic fertilizers such as muriate of potash and particularly the high doses of urea used in some cases add to the acid load on the soil. While an alternative to urea may be difficult to find use of liming materials may prove very valuable.

The effects of soil acidification on plant production are intensified by low levels of soil organic matter and therefore improvement on the latter issue would have a double positive effect.

Avoid use of dangerous chemicals

Some very dangerous pesticides are used in ploughland, fringeland, jhum, and fruit gardens. Pesticides such as Parathion (already forbidden in many countries), Dieldrin, Dichlorvos (Nogos) are highly toxic and dangerous for the environment while Diazinon (Basudin), Furadan, Mancozeb, and Malathion are toxic for many fish and wildlife species and Malathion is under increasing suspicion in relation to its toxicity for humans. The use of these chemicals should be avoided as much as possible specially when close to water sources.

Develop producers' associations

Some of the main problems stated by the farmers in relation to their activity are those related to produce marketing. Although these issues are outside the scope of this project they certainly require:

- development of producers' cooperatives and associations which could build on existing community links,
- improved road network,
- simplified and cheaper permits and taxes in the case of wood plantations.

5.2. Suggestions for Improvement of Ploughland

The use of green manure crops and incorporation of crop residue, can increase soil organic matter while maintaining high grain yields (Aulakh *et al.*, 2001). This green manure may be provided by transition crops between the dry and wet seasons, like some leguminous shrubs such as *Cajanus cajan, Indigofera tinctoria*, which can also help save 100-200 kg N/ha (Shrestha and Ladha, 1998, 2000; Shrestha *et al.*, 2002).

The System of Rice Intensification (SRI) is an alternative management system of paddy rice that basically, involves earlier transplanting of single seedlings wider spacing between them, and control of irrigation water. It has provided some good results in various countries and has been tried in Bangladesh with mixed success (Muazzam Husain, 2002; Muazzam Husain *et al.*, 2004). During our survey farmers were asked about it, but none of them were using this system and most of them answered that it would require a higher amount of labour and more careful management of seedlings and weeds. Research on this system in the CHT should be conducted to assess the possibility of its applicability.

5.3. Suggestions for Improvement of Jhum

Jhum cultivation is here to stay

Jhum cultivation will likely remain a fundamental land use system in the CHT, as in other surrounding countries (Seidenberg *et al.*, 2003), because:

- self-sufficiency in relation to rice as the main staple crop will be necessary for most households as production at a regional scale will not be sufficient to cover demand (ADB, 2001),
- the results of various government programmes show that farmers link the concept of food security to growing themselves large proportions of their food requirements rather than purchasing them (Nath *et al.*, 2005), particularly if staple crops are not available on the market (Ruf and Lançon, 2004).

Transition to alternative system faces many problems:

- diversification to cash crops is only at the reach of large land holdings or holdings with other sources of income, as has also been found for other countries in Southeast Asia (Mahanty *et al.*, 2006),
- furthermore, transport, marketing and other facilities needed for these crops in all probability will not be widely available in the region in the short term. This has already caused serious problems to fruit growers (Kamal *et al.*, 1999), so much so that cases in which horticultural producers have reverted to jhum frustrated by the control of markets by traders and transport operators have also been recorded (Do Dinh Sam, 1994; Adnan, 2004). The adequacy for rural development of many programmes designed to encourage these types of plantations remains very doubtful, not least because they lead to less land being available for smaller farmers, and therefore to shortened fallow periods (Burgers *et al.*, 2005; Rasul, 2005; Mahanty *et al.*, 2006).

That is, cash crops should not be considered as an automatic and universal alternative to jhum and certain conditions need to be met for the transition from jhum, if accepted to be successful minimising the risks to farmers (Souvanthong, 1995; Ducortieux *et al.*, 2006). Furthermore, within a given holding cash crops should also be diversified in order to help reduce risks in these uncertain circumstances of accessibility and markets.

Improve fallows in jhum

If *jhum* is to remain for some time and fallows cannot be extended for longer period due to land shortage, fallows should then be improved to perform their historical function: to allow the soil to recover after the cropping period by improving its biological, physical, and chemical characteristics.

The fallow period in jhum is the basic method to maintain the system. But a period of 4-5 years arrests the development of vegetation at a stage where biomass productivity is low (in comparison to later stages) and mineralization of organic matter is quick due to the open conditions. Therefore, recovery of soil properties is not complete.

Improved tree fallows (introducing selected species in the fallow) have frequently been suggested (Khisa, 1998; Arya, 2000; Haque, 2002) in order to maintain jhum cultivation. These introduced species should comply with two requirements:

- improve the build-up of organic matter in the soil compared to the natural fallow, and
- produce some resources to the jhumia (whether for self-consumption or selling purposes) that may compensate for the extra labour and expenses.

Bamboos could fulfil both roles. Various bamboo species, e.g. *Dendrocalamus hamiltonii*, *Bambusa arundinacea*, have shown high production of litterfall and efficient conservation of nutrients during fallow in India (Ramakrishnan, 1992; Chandrashekara, 1996) and have commercial interest. The present 4-5 year cycle does not allow bamboo to appear during the fallow period, so it may be useful to plant it after the cropping year in order to increase the return of organic matter to soils during these short fallows.

In West Java (Indonesia), bamboo-dominated fallows of 4-5 years after 2 years of cropping return soil organic matter content to about 90% of its initial content, plus producing a forest floor mass of 13.5 t/ha (not including branches) and about 19 t/ha of fine roots (Christanty *et al.*, 1996, 1997; Mailly *et al.*, 1997). These inputs may compensate for the estimated 10,000-13,000 kg/ha of organic matter that are lost during the cropping year (Ramakrishnan, 1992).

Farmers were frequently recorded in our survey stating that productivity of many crops was much better on plots reclaimed from bamboo, and this is also recognized in neighbouring countries (Do Dinh Sam, 1994).

Broom grass (*Thysanolaena maxima*) has shown a good behaviour in hedges for erosion control in the CHT, and having also commercial value (Khisa *et al.*, 2004), could therefore be useful also in improved fallows.

Indigo (*Indigofera tinctoria*) may also become a useful species for improved fallow in the future if not quite at the moment. In fact, in the 1950's it was highly regarded among the farmers in the CHT (according to Löffler, cited by Kauffmann, 1962, "not planting indigo is ritually prohibited or better, there is an obligation for planting it"). At present it has almost no commercial value, but if the trend towards the use of natural dyes instead of synthetic ones gains momentum, indigo could become a most useful species for improved fallows.

In fact, UNDP has developed a Sub-programme on the Development and Use of Natural Dyes in Textiles in India, one of the objectives of which is "the economical production of high-quality natural indigo using environmentally friendly agricultural practices" (www.undp.org.in/programme/Environment/natdye/dyejust.htm).

In Thailand, fallows improved with *Tithonia diversifolia*, *Crotolaria juncea*, or *Macaranga denticulata* have also shown increases in production in the subsequent cropping year (Yimyam *et al.*, 2003; Schelbert *et al.*, 2005). *Chromolaena odorata*, and in general species producing high amounts of litter, are judged by farmers in neighbouring countries as good fallow species giving positive yield effects on succeeding rice crops (Hoang Fagerström *et al.*, 2001).

Therefore, suggestions for improvement of the jhum system may include:

- improve fallows with various species that, both, increase the rate of return of organic matter to the soil and have some other direct interest for the farmer: comercial bamboos, leguminous shrubs (*Pueraria phaseoloides*, *Cajanus cajan*), and grasses (*Thysanolaena maxima*),

- do not use teak/gamari plantations as a substitute for fallow (see discussions in sections 4.2.6 and 5.1),
- avoid slashing and/or burning areas around gullies and steeper slopes within the jhum plot.

Improve fire management

Fire plays an important role in jhum cultivation in order to control weeds and pests, but also to check soil acidification (Szott *et al.*, 1999). Nevertheless, an unintended effect of slash burn is the frequent spread of fires to neighbouring plots. In order to decrease this risk, improvements may include:

- improved supervision by farmers during the fire,
- removing slash from the edges of the jhum plot leaving a slash-free strip as wide as possible to the neighbouring plots.

Plantations (fruit, rubber) or agroforestry are not viable alternatives for most farmers in the CHT

Spatial agroforestry systems, such as SALT and CHIAT, have been suggested and tried in the CHT as alternatives to *jhum* (Kamal *et al.*, 1999; Khan and Khisa, 2000; Nath *et al.*, 2005). Adoption of these systems has been very low, apparently due to the difficulties in managing the system. Further arguments against them may be related to the unclear performance and long-term sustainability of these systems (Hoang Fagerström *et al.*, 2001; Khisa *et al.*, 2004).

In other countries in Southeast Asia it has also been found that farmers seldom adopt these technologies unless they are paid to do so (Do Dinh Sam, 1994; Morrison and Dubois, 1998).

Similarly, fruit and rubber plantations have only been implemented through government programs or by land owners with income sources outside the farm or with relatively big amounts of land. Therefore, they do not represent a universal, or not even a widespread, alternative for farmers in the CHT.

5.4. Suggestions for Improvement of Rubber Plantations

If any new rubber plantations were to be established, the introduction of cover plants in the first years should be considered. *Pueraria phaseoloides* (which persists for 4 years) and *Calapogonium caeruleum* (which persists up to 8 years) have shown to provide almost 1,000 kg of nitrogen per hectare during these eight years and to reduce soil erosion (Pushparajah, 2001).

5.5. Suggestions for Improvement of Wood Plantations

We would like to emphasize once again that wood plantations should not be used as an alternative to fallow because they do not perform the functions expected from fallow.

Wood plantations should mix various species that, again, allow enough undergrowth and good soil cover and have commercial interest. For example, mixing teak with garjan (*Dipterocarpus turbinatus*) and *Leucaena leucocephala* increases the growth of teak and the availability of soil nitrogen and phosphorus (Haque and Osman, 1993; Kumar *et al.*, 1998).

In terms of recovering the natural forest, mixed plantations also improve the diversity of native species in relation to monospecific plantations (Kaewkrom *et al.*, 2005).

Therefore, improvements to the management of these plantations may include:

- mixing small-leave species and species producing high amounts of litter: bamboo, fruit trees, leguminous shrubs (e.g., *Cajanus cajan*) ...
- avoid the use of fire for weed control,
- decrease the density of trees in order to allow the development of undergrowth that will help control soil water erosion.

Table 3. Suggestions for improvement of the main land use systems in the Pilot Area.

	General management systems	Management details
General suggestions for all systems	• Increase organic matter applications • Use weeds for mulch or compost • Use lime in very acid soils and sensitive crops • Research on environmental and commercial use of indigo (*Indigofera tinctoria*) • Avoid use of dangerous chemicals: Parathion, Dieldrin, Dichlorvos • Research on Integrated Pest Management • - Planting trees does not guarantee soil conservation	
Ploughland	• Research on Rice Intensification System • Incorporate relay crops in dry season for green manure and saving N (cowpea)	• Use organic fertilizers: plant residues, compost, manure • Do not use urea alone, but in combination with TSP and MP
Jhum	• Improve fallows with species producing litter, fixing nitrogen and saving nutrients: bamboo, cowpea • Do not burn gullies nor steeper slopes within jhum plots	• Use weeds for mulch or compost • Do not use urea alone, but in combination with TSP and MP, and lime if possible • Keep slash-free wide margins with neighbouring plots for burning
Ginger, turmeric	• Improve fallows with species producing litter, fixing nitrogen and saving nutrients: bamboo, cowpea, indigo • Do not burn gullies nor steeper slopes within jhum plots • Dig trenches across the slope to divert runoff • Use as much mulch as possible	• Use weeds for mulch or compost • Do not use urea alone, but in combination with TSP and MP, and lime if possible • Keep slash-free wide margins with neighbouring plots for burning • Intercrop with chilli, maize, mandarin
Fruit garden	• Oranges and pineapple better on south-facing slopes • Avoid altitude over 300 m for pineapple • Ensure irrigation for drought-sensible species: litchi, mango, all Citrus, jolpai	• Keep good grass cover in the plot • Use mulch with weeds around trees • Research needed on best tree densities and pruning
Wood plantations	• Mix species, using bamboo, small-leave trees, cowpea to ensure good ground cover • Do not burn undergrowth • Research on best tree densities for tree growth and soil cover	
Forest regeneration	• If natural regeneration is not good, use plantations with many different species to improve it	• Research on introduction of *Amomum villosum* in forests

6. Conclusions

The main issues arising from this work on the land use systems of the Chittagong Hill Tracts are:

- there is a clear division between a small proportion of large households that have further sources of income from outside and mainly produce commodities and a large proportion of smaller households with little or no income from outside that mostly produce for a subsistence economy,
- wood plantations (mainly teak/gamari) have the highest estimated mean annual rate of soil erosion of all land use systems, with a clear short-term implication in terms of soil degradation,
- all the land use systems, probably with the only exception of fruit-tree plantations, face a soil organic matter crisis. There is an urgent need to increase the collection and application of organic materials (weeds, manure),
- jhum systems with short 4-5 year fallow period will likely remain important within the CHT in the near future. Two areas should be improved in these systems:
    - ♦ fallow vegetation should not be based on teak/gamari plantations but should be enriched with species returning large amounts of organic matter to the soil,
    - ♦ slashing and burning of vegetation should avoid steeper slopes and gullies within the jhum plot
- the adoption of alternative cash crops, as a significant part of the household, seems to have been restricted to the group of larger households. Similarly, the degree of adoption of spatial agroforestry systems (SALT, CHIAT) as an alternative to jhum has been quite low,
- alternatives to some of the dangerous pesticides presently used (Parathion, Dieldrin) should be promoted.

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ANNEX : SUITABILITY OF THE CHT SOIL MAP UNITS FOR SOME SELECTED CROPS

PINEAPPLE (Ananas comosus)

soil units	GLR	limitations acoording to soil map	other soil limitations	altitude	aspect
BDHAZ16	7	phosphorus (potassium)			
BDHAZ17	7	phosphorus and potassium			
BDHAZ25	7	phosphorus and potassium (base saturation)			
BDHAZ43	7	phosphorus	**Nitrogen**: very important when content is as low as 0.02%		
BDKAP07	7	phosphorus and potassium			
BDKAP12	7	phosphorus			
BDKAP24	7	phosphorus and potassium (base saturation)			
BDKAP34	7	phosphorus		although it may grow up to 600 m, the fruits will be smaller and more acid	although it may grow on any aspect, fruits will besweeter on southern aspectspecially in higher altitude
BDKAP42	7	phosphorus			
BDKAR41	NS	aeration			
BDMIR49	NS	aeration			
BDMOG11	NS	aeration			
BDRAG46	7	phosphorus	**pH** : very important when down to 3.6		
BDRAN46	7	phosphorus			
BDSUB47	7	phosphorus			
BDTEI08	8	phosphorus (potassium)			
BDTEI30	7	phosphorus and potassium (base saturation)			

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

CASHEW NUT (Anacardium occidentale)

soil units	GLR	limitations acoording to soil map	other soil limitations	altitude	aspect
BDHAZ16	7	phosphorus	**Nitrogen**: important when content is as low as 0.02% **pH**: important when down to 3.6	not over 400 m	better on southern aspect as it is very tolerant of rought
BDHAZ17	7	phosphorus and potassium			
BDHAZ25	7	phosphorus and potassium (base saturation)			
BDHAZ43	7	phosphorus			
BDKAP07	7	phosphorus (potassium and base saturation)			
BDKAP12	7	phosphorus			
BDKAP24	7	phosphorus (potassium and base saturation)			
BDKAP34	7	phosphorus (base saturation)			
BDKAP42	7	phosphorus			
BDKAR41	7	phosphorus (water logging)			
BDMIR49	NS	aeration			
BDMOG11	NS	aeration			
BDRAG46	7	phosphorus			
BDRAN46	7	phosphorus			
BDSUB47	7	phosphorus			
BDTEI08	7	phosphorus			
BDTEI30	7	phosphorus and potassium (base saturation)			

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

LEMON (Citrus limon)

soil units	GLR	limitations acoording to soil map	other soil limitations	altitude
BDHAZ16	8	phosphorus (potassium)	**pH**: extremely important when down to 3.6 **Nitrogen**: very important when content is as low as 0.02% **Water** important in February on dry soils	up to 600 m
BDHAZ17	8	phosphorus and potassium		
BDHAZ25	8	phosphorus and potassium (base saturation)		
BDHAZ43	8	phosphorus (potassium)		
BDKAP07	8	phosphorus and potassium		
BDKAP12	8	phosphorus		
BDKAP24	8	phosphorus and potassium (base saturation)		
BDKAP34	8	phosphorus		
BDKAP42	8	phosphorus		
BDKAR41	8	phosphorus (aeration and potassium)		
BDMIR49	8	aeration and phoshorus (potassium)		
BDMOG11	8	aeration and phoshorus (potassium)		
BDRAG46	8	phosphorus (potassium)		
BDRAN46	8	phosphorus		
BDSUB47	8	phosphorus (potassium)		
BDTEI08	8	phosphorus (potassium)		
BDTEI30	8	phosphorus and potassium (base saturation)		

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

MANDARIN (Citrus reticulata)

soil units	GLR	limitations acoording to soil map	other soil limitations	altitude
BDHAZ16	8	phosphorus (potassium)		
BDHAZ17	8	phosphorus and potassium		
BDHAZ25	8	phosphorus and potassium (base saturation)		
BDHAZ43	8	phosphorus (potassium)	**pH**: extremely important when down to 3.6	
BDKAP07	8	phosphorus and potassium		
BDKAP12	8	phosphorus		
BDKAP24	8	phosphorus and potassium (base saturation)		
BDKAP34	8	phosphorus	**Nitrogen**: very important when content is as low as 0.02%	
BDKAP42	8	phosphorus		
BDKAR41	8	phosphorus (aeration and potassium)		not over 400 m
BDMIR49	8	aeration and phoshorus (potassium)		
BDMOG11	8	aeration and phoshorus (potassium)		
BDRAG46	8	phosphorus (potassium)	**Water** important in February on dry soils	
BDRAN46	8	phosphorus		
BDSUB47	8	phosphorus (potassium)		
BDTEI08	8	phosphorus (potassium)		
BDTEI30	8	phosphorus and potassium (base saturation)		

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

CITRON (Citrus medica)

soil units	GLR	limitations acoording to soil map	other soil limitations	altitude
BDHAZ16	8	phosphorus (potassium)		
BDHAZ17	8	phosphorus and potassium		
BDHAZ25	8	phosphorus and potassium (base saturation)		
BDHAZ43	8	phosphorus (potassium)	**pH**: extremely important when	
BDKAP07	8	phosphorus and potassium	down to 3.6	
BDKAP12	8	phosphorus		
BDKAP24	8	phosphorus and potassium (base saturation)		
BDKAP34	8	phosphorus	**Nitrogen**: very important when	
BDKAP42	8	phosphorus	content is as low as 0.02%	
BDKAR41	8	phosphorus (aeration and potassium)		up to 600 m
BDMIR49	8	aeration and phoshorus (potassium)		
BDMOG11	8	aeration and phoshorus (potassium)	**Water** important in February on	
BDRAG46	8	phosphorus (potassium)	dry soils	
BDRAN46	8	phosphorus		
BDSUB47	8	phosphorus (potassium)		
BDTEI08	8	phosphorus (potassium)		
BDTEI30	8	phosphorus and potassium (base saturation)		

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

ORANGE (Citrus sinensis)

soil units	GLR	limitations according to soil map	other soil limitations	altitude
BDHAZ16	7	phosphorus (potassium)		
BDHAZ17	7	phosphorus and potassium		
BDHAZ25	7	phosphorus and potassium (base saturation)	**pH**: very important when down to 3.6	
BDHAZ43	7	phosphorus		
BDKAP07	7	phosphorus and potassium		
BDKAP12	7	phosphorus		
BDKAP24	7	phosphorus and potassium (base saturation)		
BDKAP34	7	phosphorus	**Nitrogen**: very important when content is as low as 0.02%	
BDKAP42	7	phosphorus		up to 600 m
BDKAR41	8	phosphorus and aeration		
BDMIR49	8	aeration and phoshorus		
BDMOG11	8	aeration and phoshorus		
BDRAG46	7	phosphorus	**Water** important in February on dry soils	
BDRAN46	7	phosphorus		
BDSUB47	7	phosphorus		
BDTEI08	8	phosphorus (potassium)		
BDTEI30	7	phosphorus and potassium (base saturation)		

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

LITCHI (Litchi chinensis)

soil units	GLR	limitations according to soil map	other soil limitations	altitude
BDHAZ16	7	phosphorus (potassium)		
BDHAZ17	7	phosphorus and potassium		
BDHAZ25	7	phosphorus and potassium (base saturation)		
BDHAZ43	7	phosphorus	**pH**: extremely important when down to 3.6	
BDKAP07	7	phosphorus and potassium		
BDKAP12	7	phosphorus		not over 400-500 m, although cultivars such as "No Mai Chee"and "Wai Chee" are more resistant to cold
BDKAP24	7	phosphorus and potassium (base saturation)		
BDKAP34	7	phosphorus	**Nitrogen**: very important when content is as low as 0.02%	
BDKAP42	7	phosphorus		
BDKAR41	8	phosphorus and aeration		
BDMIR49	NS	aeration and phoshorus		
BDMOG11	NS	aeration and phoshorus		
BDRAG46	7	phosphorus	**Water** important in February on dry soils	
BDRAN46	7	phosphorus		
BDSUB47	7	phosphorus		
BDTEI08	8	phosphorus (potassium)		
BDTEI30	7	phosphorus and potassium (base saturation)		

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

MANGO (Mangifera indica)

soil units	GLR	limitations acoording to soil map	other soil limitations	altitude
BDHAZ16	7	phosphorus, potassium, and nitrogen	**pH**: very important when down to 3.6 **Nitrogen** fertilizer in excess of1.8 kg/tree produces damages **Water** needed to get good production during the 4-6 weeksafter fruit set	not over 600 m
BDHAZ17	7	phosphorus, potassium, and nitrogen		
BDHAZ25	7	phosphorus, potassium, and nitrogen (base saturation)		
BDHAZ43	7	phosphorus, potassium, and nitrogen		
BDKAP07	7	phosphorus, potassium, and nitrogen (base saturation)		
BDKAP12	7	phosphorus and nitrogen		
BDKAP24	7	phosphorus, potassium, and nitrogen (base saturation)		
BDKAP34	7	phosphorus and nitrogen (base saturation)		
BDKAP42	7	phosphorus and nitrogen		
BDKAR41	7	phosphorus and nitrogen (potassium)		
BDMIR49	7	phosphorus and nitrogen (aeration and potassium)		
BDMOG11	7	phosphorus and nitrogen (aeration and potassium)		
BDRAG46	7	phosphorus, potassium, and nitrogen		
BDRAN46	7	phosphorus and nitrogen		
BDSUB47	7	phosphorus and nitrogen (potassium)		
BDTEI08	7	phosphorus, potassium, and nitrogen		
BDTEI30	7	phosphorus, potassium, and nitrogen (base saturation)		

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

GUAVA (Psidium guava)

soil units	GLR	limitations acoording to soil map	other soil limitations	altitude
BDHAZ16	8	phosphorus, potassium		
BDHAZ17	8	phosphorus, potassium		
BDHAZ25	8	phosphorus, potassium (base saturation)		
BDHAZ43	8	phosphorus, potassium	**pH**: very important when down to 3.6	
BDKAP07	8	phosphorus, potassium		
BDKAP12	8	phosphorus		
BDKAP24	8	phosphorus, potassium (base saturation)		
BDKAP34	8	phosphorus	**Nitrogen**: very important when content is as low as 0.02%	
BDKAP42	8	phosphorus		up to 600 m
BDKAR41	8	phosphorus and aeration (potassium)		
BDMIR49	8	aeration and phosphorus (potassium)		
BDMOG11	8	aeration and phosphorus (potassium)		
BDRAG46	8	phosphorus, potassium		
BDRAN46	8	phosphorus	Although drought-tolerant, **Water** needed to get good production during flowering and fruit development	
BDSUB47	8	phosphorus (potassium)		
BDTEI08	8	phosphorus, potassium		
BDTEI30	8	phosphorus, potassium (base saturation)		

soil units: correspond to those of the soil map

GLR: greatest limitation rating. On a scale 0-9 (where 9 is a very strong limitation for the crop, and 1 a very low limitation), the rating of the soil/climate charateristic producing the highest limitation.

NS: not suitable; the degree of limitation is so high that the species will not be able to survive or grow in that unit.

limitations according to soil map: soil/climate charateristics producing the highest limitation. Those in brackets present some limitation but not so strong as those outside the brackets. Such limitations reflect the description in the soil map (e.g., the phosphorus, potassium, nitrogen content, etc.)

other soil limitations: these are limitations obtained when using some characteristics, not as they are reflected in the soil map, but as in some other soil reports with data from the CHT. This has been done to take into account the possibility of encountering soils in which nitrogen, pH, phosphorus, potassium are lower than those reported in the soil map

 

 

The environment in the Chittagong Hill Tracts (CHT) is under pressure. New methods must be developed, applied, and tested for sustainable management of the natural resources. Practical information is required at both the field and policy level. The Chittagong Hill Tracts improved natural Resources Management (CHARM) project aims at building capacity of different stakeholder groups for promoting sustainable natural resources management in the Chittagong Hill Tracts (CHT). CHARM targets a better understanding of sustainable management of the natural resources and the provision of an improved information basis for decision making with involvement and participation of target groups.

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