CONCLUSION

9.1. Soil degradation class

The soil erosion class, degree, extent and severity of soil degradation of the degraded and moderately degraded sites were evaluated based on the criteria by Sehgal and Abrol (1994) and USDA Soil Survey Manual (1995). Finally, degradation class of the degraded (DF) and moderately degraded (MDF) sites were classified as compared to the undegraded forest (UDF) site in terms of code numbers as given in table 9.1. Soil degradation class of the degraded site and moderately degraded sites are 3(2.5) and 1(1.3) respectively as compared to the undegraded site.

Degraded forest site: 3(2.5)

Erosion Class (3)

Soils in the degraded (DF) site have lost >75% of A or E horizons of uppermost 20cm and there is exposure of the materials below A or E horizons to the atmosphere. The soils in this site will be difficult for restoration at farm level

Degree of degradation (Moderate, 2)

The soils have greatly reduced agricultural productivity in terms of economic value

Extent of degradation (Dominant, .5)

More than 50% of the total area in this site is affected by soil degradation

High Severity

The site has a significant loss in 1/3 to 2/3 of agricultural productivity and the affected area not economical to cultivate but can be used as agroforestry system.
Table 9.1. Erosion class, degree, extent, severity and degradation class of degraded (DF) and moderately degraded (MDF) forest sites

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>DF</th>
<th>MDF</th>
<th>UDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion class*</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Degree of degradation**</td>
<td>Moderate (2)</td>
<td>Slight (1)</td>
<td>0</td>
</tr>
<tr>
<td>Extent of degradation**</td>
<td>Dominant (.5)</td>
<td>Common (.3)</td>
<td>0</td>
</tr>
<tr>
<td>Severity of degradation**</td>
<td>High</td>
<td>Low</td>
<td>0</td>
</tr>
<tr>
<td>Degradation class</td>
<td>3(2.5)</td>
<td>1(1.3)</td>
<td>0</td>
</tr>
</tbody>
</table>

**Soil Degradation Status & Impacts (Abrol & Sehgal, 1994)
Moderately degraded site: 1(1.3)

Erosion Class (1)

Soils in this site have lost <25% of A or E horizons of uppermost 20cm soil but this soil can be restorable at form level. The surface soil layer thickness of this site is in the normal range.

Degree of degradation (Slight, 1)

The soils in this site has somewhat reduced agricultural productivity as compared to the undegraded site

Extent of degradation (Common, .3)

About 10-2% of the total area in this site is affected by soil degradation

Low severity

The soil has lost up to a maximum of 15% in agricultural productivity which is negligible and easily manageable

9.2. Microbial communities and their activities

Microbial populations of bacteria and fungi, including vesicular-arbuscular mycorrhizal fungi (VAMF) population in the sites showed long term detrimental impact of soil utilization by shifting cultivation for agricultural production and selective logging of trees as comparison to the undegraded site. Even after 5 years (1993-1997) of regeneration period, microbial community structure and activities in the degraded site could not restore up to half of the undegraded forest soil. The microbial activities as measured in terms of soil enzyme activities, dehydrogenase, acid phosphatase and urease activities also declined in degraded and moderately degraded forest sites as a result of shifting cultivation and selectively logging practices accompanied by burning of the soil surface. The rate of decline was significantly higher in the degraded site than in moderately degraded site for
all the biological and biochemical characteristics of soil as compared to the undegraded forest site at surface and subsurface soil layers.

Therefore, it may be concluded that the microbiological communities and their activities as measured by population status of bacteria and fungi, vesicular-arbuscular mycorrhizal fungi (VAMF), microbial biomass C and N and soil enzyme activity were drastically decreased in soils which had been used for shifting cultivation for long time without proper input of nutrients either based on organic or inorganic fertilizers. Similarly, there was decline in fertility status of soils in moderately degraded site that has been continuously used for selective logging as comparison to an undegraded natural forest in the north-eastern hill region.

The culture-independent analysis of the bacterial genomic diversity as revealed by gel compare analysis of the 16S rDNA gene from the DGGE profiles had a similar results of bacterial community structure to that of the cultivation-dependant studies. The cluster analysis of the DGGE bands of 16S rDNA genes revealed a clear separation of the degraded and moderately degraded sites from that of the undegraded site in terms of bacterial genomic communities.

Total PLFA contents of the soils expressed in $\mu$Mol kg$^{-1}$ revealed that there was no significant variation on microbial population numbers among the three study sites at the surface soil layers though the subsurface soil contain lower amounts of the PLFA in general. There was a decline in the microbial diversity status of the degraded sites at both the soil depths in comparison to the moderately degraded and undegraded sites as revealed by the PLFA
profiles. The undegraded forest site contained maximum diversity of the PLFA fractions and their individual fatty acids revealing a higher microbial diversity than the moderately degraded and degraded site respectively.

9.3. Fertility status of soils

Based on the results of all measured parameters it can be inferred that the shifting cultivation and selective logging practices in humid tropical hill forest soils caused significant decrease in physico-chemical, biological and biochemical properties and thus affecting soil fertility status. It is clear from the results that there were significant decline in the important physico-chemical, biological and biochemical characteristics of the soils in degraded and moderately degraded forest sites as compared to the undegraded site. The sharp decline in important plant nutrients such as organic C as an indicator of soil organic matter, total N and ammonium N among the chemical characteristics revealing decline in fertility status of the soils in degraded and moderately degraded sites as a consequence of soil degradation due to shifting cultivation and selective logging practices. However, the undegraded site being undisturbed for any type of soil utilization in the past maintained the important soil nutrients along with higher organic C content, thus higher soil fertility in this site.

9.4. Discriminant function analysis (DFA).

Two canonical discriminant functions (CDFs) were obtained from the DFA which together contributed a total of 100 per cent variance among the three study sites (Table 7.3). Canonical discriminant function 1 (CDF1) was the most important function due to its higher Eigenvalue (31.1829) and
canonical correlation (0.9843). This function accounted for a maximum variation in soil degradation types in the present study with a variance percentage of 85.88 as compared to the canonical discriminant function 2 (CDF2). The other variables in CDF 2 namely, microbial biomass C, dehydrogenase activity, total N, soil pH and soil temperatures were also important in discriminating the soil degradation types between the three study sites but their absolute correlation with the discriminant function were negative or comparatively lower to the bulk density. Therefore, the soil characteristics in CDF1 and CDF2 were found to be sensitively responsive to the soil degradation caused by shifting cultivation and selective logging practices in the hill forest soils. These parameters namely, organic C, bulk density, microbial biomass C and dehydrogenase soil enzyme activity may be used to assess the degradation status of soil in the hill region in particular and other soil in general.