Some of the major concerns related to livelihood improvement are maintaining soil fertility, degradation of community lands, increasing farm income, building capacity of the community, and decreasing women’s workloads. Several questions arose concerning these issues and PARDYP tested and synthesised a number of options to address them.

**How Can Farmers Maintain or Improve Soil Fertility?**

Soil fertility is a key concern of every farmer. Soil fertility can be supported through appropriate agronomic practices as well as appropriate use of fertilisers. PARDYP tested various agronomic practices in the different project watersheds. The main agronomic practices considered were inter-cropping, crop rotation, mulching, and liming. The main soil fertility management options were pit composting, black plastic composting, vermicomposting, and use of effective micro-organisms (EM) (rhizobium, azatobacter, and boakshi). The tests in PARDYP-Nepal focused on on-farm composting using black plastic and EM, and lime application in acidic soils. PARDYP-Nepal also monitored leachate in the soil erosion monitoring plots in agricultural and degraded land to help understanding of the nutrient dynamics in the soil profile.

**On-farm composting**

Compost or farmyard manure has played a crucial role in maintaining and building up soil fertility in Nepal. Many different composting methods were tested and demonstrated in the Jhikhu Khola watershed. Among the different methods, farmers considered black plastic covered composting as recommended by the Sustainable Soil Management Project to be the best.

Black plastic composting was first tested with 16 farmers in 2004. By 2005, about 50 farmers had started using this method in the Jhikhu Khola watershed. In this method, a traditional compost heap is covered with a piece of black plastic, which protects nutrients from leaching during rainy days and provides a favourable environment (increased temperature and decreased evaporation loss) for the growth of microbes (Figure 33). The method is based on a passive aeration approach, the black plastic is removed from the compost heap for a short period each day. Using this method, compost decomposed within 45-50 days compared to about 4-6 months without the plastic sheet. Black plastic (thickness ~ 800 µm) is light, easy to use, and durable. Compost is produced with less time and labour than by the standard method.

Use of **effective micro-organisms (EM)** is another method being adopted by the watershed residents. In this method, composting is based on aerobic decomposition and
again it takes about 45 days to decompose fresh materials rather than 4-6 months. Effective microorganisms (EM) refer to a mixed microbial culture of selected species such as lactic acid bacteria, yeasts, photosynthetic bacteria, and actinomycetes. All of these are natural, compatible with one another, and coexist in liquid culture. In this method, locally available raw organic materials such as crop residues, plant leaves, and grasses are used as fertilising resources. The ingredients are mixed together and piled in multiple layers; the EM solution is sprinkled between layers together with old compost as microbial inoculums. Water is also sprinkled on each layer to ensure the moisture content. The pile is covered with a plastic sheet; 3-4 wooden poles are inserted vertically to provide sufficient ventilation, and the pile is turned every 10 days (Figure 34). Moisture status is monitored and water is sprinkled on the heap if deficiency is observed. The general practice in the Jhikhu Khola watershed is to use about 1,000 kg of the fresh ingredients, about 500 litres of water, 250 kg old compost, and about 1 litre of EM solution. EM is easily available in the local markets and is cheap.

**Soil acidification and lime experiment**

The soil survey showed that soil acidification problems were similar in both watersheds (Table 14). In both watersheds about 80% of soils tested had a low pH (~5.0). Extensive use of chemical fertilisers (particularly urea and ammonium based fertilisers), presence of partially decomposed pine litter in farmyard manure, and acidic bedrock (sandstone, siltstone, and quartzite) are among the factors contributing to acid soil (Schreier and Shah 1999).
Soil acidification, associated with high inputs of acid-causing fertilisers (urea and ammonium based fertilisers) and acid bedrock geology, is becoming a major problem in the double and triple crop rotation systems in the Jhikhu Khola area. Chitrakar (1990), Sherchan and Baniya (1991), and Suwal et al. (1991) noted that the commonly used fertilisers, ammonium sulphate and urea, tend to acidify soils. This acidification has serious implications as low soil pH (< 5.0) slows the rate of organic matter decomposition, and leads to the leaching of base cations (calcium and magnesium) and the fixing of available phosphorous in the soil – making it unavailable to plants – and to aluminium toxicity and micronutrient deficiencies (Shah 2003).

PARDYP investigated whether pine litter in compost was contributing to soil acidification on red soils originating from phyllitic parent materials and brown (non-red) soils from quartzitic materials. Twelve 50 x 50 cm plots were established; six plots each were assigned for red and non-red soils. Plots of one red and one non-red soil were combined to make six sets of treatments. In the first set of plots, 1 kg per m² of dry pine litter was incorporated, and the same amount of pine litter was added 2 times in the 2nd, 3 times in the 3rd, 4 times in the 4th, 5 times in the 5th, and 6 times in the 6th set at intervals of six months. The soil was analysed for pH, exchangeable cations, carbon, and available phosphorous (Bray-1) using standard procedures (after Schreier and Shah 2000). No acidification was detected after the first year, but after the second year there was clear evidence that soil acidification was taking place. Initially the rate of acidification was higher in the non-red soils on quartzite bedrock, while the red soils resisted acidification. During the second year, the trend towards greater acidification was significant in both soils. While the carbon and calcium content improved with pine litter addition, the pH decreased. In the non-red soils, the available phosphorous content increased, but not in the red soils where the low levels remained the same throughout the experiment. This suggests that pine litter is acidifying the soils and that in the process the phosphorous availability in the red soils is impaired. While there are benefits from improving carbon and calcium values by pine litter addition, the negative effect on acidity outweighs them. These results suggest that the addition of other types of litter is needed to have a positive impact on nutrient management (Schreier and Shah 2000). Earlier PARDYP experiments showed that acidification is a slow process and that different soils respond differently. In general this is a long-term problem seen by researchers, but farmers tend not to see it as a serious problem because it is not yet affecting their yields.

Intensification and in particular cash crop production has influenced the nutrient budget and soil nutrient pool of irrigated and rainfed lands. No changes were observed in soil pH between intensively and less intensively farmed sites, but a slight decline was noted in
irrigated fields and a slight increase in rainfed fields. Intensification has not led to more acidic soils as the soils are already acidic and would probably need higher levels of acidic inputs to cause further acidification. Also the calcium-enriched irrigation water tends to buffer the effects of soil acidity in irrigated sites (Shah 2003).

PARDYP tested the effects of applying lime to the acidic soils of the Jhikhu Khola watershed. Eight sites with low soil pH were selected. A recommended dose of lime was applied to five ropanis of land (1 ropani = 508 m$^2$) by each of three farmers (three sites) in Lamdihi to test its effects on maize – for example: 120, 230, and 294 kg of lime per ropani on clay loam soil with pH 6.0, 5.5, and 5.2 respectively, as per Agriculture Development Diary 2005 (AICC 2005). Likewise, lime was applied to five vegetable farming sites (cauliflower, potato, tomato, and brinjal). At each site control plots were established, and soil pH and production before and after lime application studied. The results showed a slight increase in soil pH (by 0.1-0.3) after one crop season following lime application. Interestingly, the production of potato increased by about 50% in plots where lime was applied. A few research farmers pointed out that it was easier to till the land after lime application. The effect of lime on soil pH and production demands much more intensive scientific study, including cost:benefit analysis, proper design, and accuracy of measurement.

**Leachate Study in the Jhikhu Khola Watershed**

Nutrient loss through leaching reduces soil fertility and thus production. PARDYP monitored leaching in its soil erosion monitoring plots on agricultural and degraded land to understand the nutrient dynamics in the soil profile, which might be very important for sustainable soil fertility management.

The leachate volume (6 to 58% of rainfall) in rainfed agricultural land was significantly higher than runoff (2 to 7% of rainfall), whereas in degraded land the leachate volume (12 to 16% of rainfall) was slightly lower than runoff (18 to 29% of rainfall). The total leachate volume was higher in agricultural land than in degraded land, ranging from 541 to 4,712 m$^3$/ha in rainfed agricultural land and from 389 to 865 m$^3$/ha in degraded land. The reason might have been the effect of the red soil in the degraded plot, which was very compact due to inadequate vegetation resulting in low infiltration. The agriculture plots were somewhat levelled, and due to soil working for cultivation, infiltration in agricultural land is significantly higher than in degraded land. Also, farmers apply chemical fertilisers to rainfed agricultural land while no chemical fertilisers are applied to degraded land (see Annex 15).

In rainfed agricultural land, nitrate leaching ranged from 306 to 2,518 kg/ha, which is equivalent to 147 to 1,230 kg/ha of urea fertiliser. Leaching of nitrate from degraded land ranged from 59 to 237 kg/ha, equivalent to 29 and 115 kg/ha of urea fertiliser. Phosphate leaching ranged from 5 to of 94 kg/ha in rainfed agricultural land, equivalent to 3 to 66 kg/ha of diammonium phosphate (DAP) fertiliser, while from degraded land it ranged from 1 to 5 kg/ha, equivalent to 1 to 3 kg/ha of DAP fertiliser. Potassium