Chapter 5

Understanding Degradation Processes in the Middle Mountains of Nepal

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Abstract

The processes of deforestation, soil erosion, and soil fertility deterioration are discussed in a case study on the Jhikhu Khola Watershed, 50km east of Kathmandu, Nepal. Forest degradation over the past 50 years has not been gradual but has passed through at least two major cycles of active deforestation, followed by afforestation. Unfortunately, the afforestation period has never been sufficient to re-establish the former forest and its soil-productive capacity. Removal of forest cover and excessive collection of litter, firewood, and fodder have left the forests in a highly depleted state, with chances of recovery being slow and difficult. Recent afforestation efforts have focussed on intermediate slopes, while agricultural expansion has occurred on steeper and more marginal slopes. This is leading to higher soil erosion losses in spite of well-adapted indigenous techniques to divert runoff. Large pre-monsoon storms are responsible for massive losses of soil, and these degraded areas in turn are the largest contributors to sedimentation. Agroforestry efforts are needed to rehabilitate these degraded sites since they currently produce little biomass and make the largest contributions to sediment load.

Introduction

Renewed concern about the rapid growth of the global population is once again raising the question about the capacity of the globe to supply sufficient food to meet increasing demand (Bongaarts 1994). This predicament is nowhere more apparent than in China where large numbers of rural people have migrated to urban centres where their consumption habits have shifted from basic staples to a more meat rich diet (Brown 1994). The question is increasingly being asked: "Can agricultural intensification meet the demand or is expansion of the agricultural land base necessary?" (Penney and Solberg 1994). It is likely that both these processes will be needed. As is evident from experience in the developed world, agricultural intensification has resulted in very widespread soil and water pollution problems (Hallberg 1989, Schuyler 1994, Owens 1994). Since high quality agricultural land is scarce, agricultural expansion will mean converting marginal lands for cultivation. This will mean great environmental risks, resulting in further deterioration of soil and water resources. Both of these processes dominate land use in the Himalayan region of Nepal. Some of the resulting degradation processes are described in this paper.

A case study is presented from the Jhikhu Khola Watershed located in the middle mountains of Nepal, 50km east of Kathmandu. This shows that the basin is used intensively for agriculture. Double and triple annual crop rotations are widespread. The land-use dynamics and degradation processes have been monitored over the past five years in this 11,000ha watershed. The specific focus of this paper is to highlight: a) deforestation, b) soil erosion, and c) soil nutrient declines.

It is our belief that rehabilitation programmes are unlikely to succeed if the processes of degradation (socioeconomic and biophysical) are not well understood. However, in this presentation the discussion is confined to the biophysical processes.

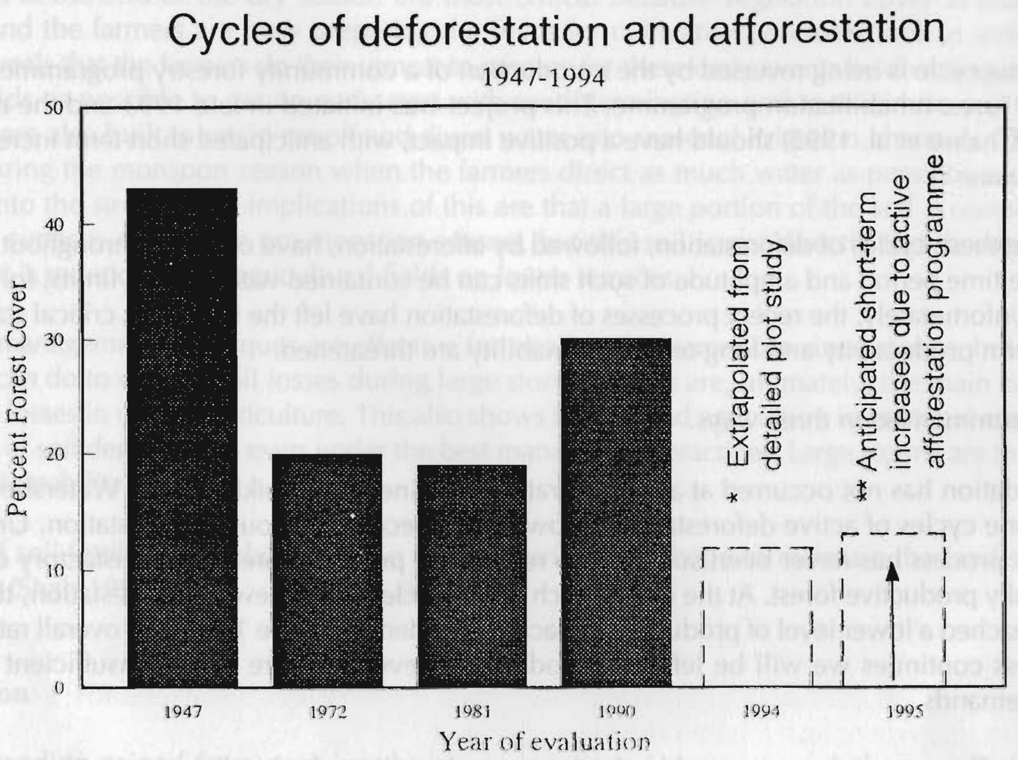
Forest Dynamics and Deforestation

Much has been written about rapid deforestation in the middle mountains and the resultant findings are often contradictory. The World Bank presented a rather bleak picture on the rate of deforestation in 1979

(FAO/World Bank, 1979), while Gilmour and Fisher (1991) suggested that in many places the forests have actually improved.

Using historic land-use maps from 1947 and 1981 and large-scale aerial photos from 1972 and 1990, a quantitative evaluation has been carried out to determine the historic forest dynamics in the Jhikhu Khola Watershed. All information was digitised and the changes were quantified using the GIS overlay technique. The results from this evaluation are provided in Figure 1 which shows a rapid rate of deforestation in the 1950s. This is attributed to the initiation of the Forestry Act in 1957 which gave the responsibility for managing the forests to the National Forestry Department. During the transition period, many forests were cleared under the assumption that, once the trees were removed, ownership would revert to the local farmers or local community. But this did not happen, instead the results were a marked decline in forest cover over about a 25-year period. In the early 1980s, active afforestation programmes were introduced through the Nepal-Australia Forestry Programme. Large areas were converted into forests over a 10-year period by initially creating chir pine plantations, with the expectation that, once the forest was well established, native secondary forest cover would become predominant and the pine could then be removed by harvesting the trees for timber and firewood. The GIS analysis shows that forest cover, indeed, expanded over this period and almost 50 per cent of the previously removed forests were re-established.

Figure 1: Cycles of deforestation and afforestation in the Jhikhu Khola Watershed Based on historic maps, aerial photo interpretations, and plot analysis



Unfortunately, the ever-increasing demand for animal feed could only be met by harvesting all palatable secondary forests and many pine plantations which were 10-15 years old. These forests have marginal utility for the local people since they neither provide good firewood nor animal feed. The removal of the understorey for animal feed, and the use of forest litter to supplement organic matter input for agriculture, left many of these forests depleted of nutrients and devoid of palatable biomass with little protective cover against soil erosion. To make matters worse, the selective GIS analysis showed that most of the forests established in the 1980s were planted on intermediate slopes (20-35%), while a proportionately larger expansion of agriculture occurred on steeper slopes (36-49%). This is quite contrary to conventional wisdom which favours forest cover on steep slopes for soil conservation and the use of the more gently sloping terrain for agriculture. It can thus be concluded that, during this period, the forest cover expanded but the quality, as well as the biodiversity, of the forests declined.

In the last two years, a new phase of deforestation has occurred and this is attributed to democratisation. The impact of the forests over the past five years was measured by re-sampling 12 forest plots (20x20m size) which were originally calibrated in 1989 (Schmidt et al. 1993, Feigi 1989). These plots are widely distributed throughout the watershed and cover private and community forests, as well as forests controlled by the National Forestry Department. A total number of 614 trees was measured for standing biomass in 1989, and five years later the forest plots were re-surveyed to establish forest use dynamics and biomass growth. A total of 386 trees was lost during this five-year period, representing 63 per cent of the trees originally surveyed. This represents an average loss of 28 per cent over the 12 plots. Three plots, located in a well protected community forest suffered no tree losses, while all the trees were removed from two plots previously under private ownership. All other plots had small to very large losses. A further point of interest is that sal trees (*Shorea robusta*) and not chir pine were the preferred species removed. The losses were in part attributed to democratisation, and this resulted in several local groups reacting against former landowners who were no longer in political favour. The frustration experienced by local farmers was further accentuated by the delay in transferring the management and control of the forests from the national agency to local community groups. An additional factor was the increasing demand for firewood resulting from population increase and the associated demand for bricks for house construction. *Sal* wood provides a far superior heating source to fire the bricks than chir pine. These have been the predominant reasons for the most recent decline in forest cover.

Once again the cycle is being reversed by the introduction of a community forestry programme initiated by the ICIMOD forest rehabilitation programme. This project was initiated in late 1993 and the results of the programme (Chalise et al. 1995) should have a positive impact, with anticipated short-term increase in forest cover (see Figure 1).

It is likely that these cycles of deforestation, followed by afforestation, have occurred throughout history, but, as long as the time period and amplitude of such shifts can be contained within small limits, forest recovery is possible. Unfortunately, the recent processes of deforestation have left the forest in a critical stage in which both short-term productivity and long-term sustainability are threatened.

This can be summarised in three ways.

Forest degradation has not occurred at a gradual rate of decline in the Jhikhu Khola Watershed. Instead, it has undergone cycles of active deforestation followed by a recovery through afforestation. Unfortunately, the recovery process has never been sufficient to restore the previous forest to a satisfactory degree or re-establish a fully productive forest. At the end of each down cycle after renewed deforestation, the forest site conditions reached a lower level of productive capacity as evident in Figure 1, with an overall rate of decline. If this process continues we will be left with productivity levels that are clearly insufficient to meet the increasing demands.

The forest decline cannot be measured by forest cover alone. It is the biodiversity, understorey biomass, forest floor coverage of the soil, and the annual biomass yield that give the true picture of forest productive capacity.

The removal of all understorey and forest litter is resulting in a marked decline in forest soil fertility, since nutrient cycling via forest litter is interrupted. These same processes also result in significant soil losses through erosion, since the natural protective capacity of forests is no longer effective. It is clear that the combination of these processes leads to non-sustainability of the forests, and the long-term production and protection capacities of the forests are in jeopardy.

Soil Erosion Processes

As part of the land-use dynamics, it was shown that agricultural expansion has mostly occurred on steeper and more marginal slopes, and this has serious environmental consequences, particularly in relation to soil erosion. As part of our study we measured soil erosion from upland and dryland agricultural sites. This was accomplished by monitoring five plots of 100sq.m. each through three monsoon seasons from 1992-1994. All plots were established in the upper portions of the watershed and were built in such a way as to cover a sequence of two terraces. All runoff and sediments were collected in a series of three drums, and after each storm the accumulated water and sediments were quantified. The results showed that the erosion between storms and between plots was highly variable. The measured rates ranged from one to 43 tonnes per hectare per year over the three-year period of monitoring. Given the weathering rates in this region, we can assume that a 15 tonne per hectare soil loss is tolerable. What our results also indicate is that physical surface conditions are of great importance. Two plots were established on relatively coarse-textured soils with high infiltration capacities. Very little runoff occurred from these two sites throughout the three years. In contrast, the three plots on finer textured soils all reached levels that are of concern for the long-term maintenance of the agricultural production capacity. What is even more important is the fact that 50 per cent of the annual sediment load occurred in one single storm and 80 per cent in two storms. This suggests that the large storm events have the greatest impact on upland agriculture, and these, in turn, are also the most difficult for farmers to control.

When we examined the runoff and sediment transport in the stream, we found that the sediment rating curve for the pre-monsoon season was consistently higher than during the monsoon season. This suggests that the early storms at the end of the dry season are most critical because vegetation cover at that time is at a minimum and the farmers are busy preparing the fields for cultivation. A closer look at indigenous farm practices reveals that the farmers do their utmost to prepare for these early events by diverting as much water into the fields as possible to get an early start with seed germination and to minimise erosion. Many of checkdams are also built to retain runoff and divert water into seasonal irrigation channels. This process is reversed during the monsoon season when the farmers direct as much water as possible away from their fields and into the stream. The implications of this are that a large portion of the soil is removed from the agricultural surfaces during the pre-monsoon season, but this soil is not directly lost through the stream transport but is redeposited in agricultural fields on lower terraces.

All of these management techniques are effective for small and intermediate sized storms, but there is little the farmers can do to control soil losses during large storms. These are, ultimately, the main culprits of soil and nutrient losses in upland agriculture. This also shows that upland agriculture in marginal areas has a high risk in terms of soil degradation, even under the best management practices. Large storms are thus a constant threat to sustainability.

The topic of soil fertility degradation is also of importance if we hope to maintain the land's capacity for productivity (Shah 1995).

Rehabilitation

The understanding gained from studying the above-mentioned processes was then applied to initiate a rehabilitation programme in the watershed. A demonstration site was selected where soil degradation had advanced to a point at which the soils were deeply gullied and surface vegetation was minimal. This was one of the most degraded sites in the lower portion of the Andheri Khola. The site is about two hectares in size, has deep gullies with dissected red soils on intermediate to steep slopes, and can be classified as a badland landscape. The site was chosen because the area contributes a very large proportion of the total annual stream sediment load, and this creates problems with irrigation in the downstream portion of the basin. It is also the only non-productive area in the watershed and rehabilitation will significantly improve the moisture regime, reduce the sediment production from streamflow in the watershed, and produce much needed biomass.

Our rehabilitation programme consists of establishing a tree nursery entirely made up of native nitrogen-fixing fodder trees. A series of hedgerow terraces was formed to stabilise the soils and to improve nitrogen and organic matter in the soils. Some of the soils were modified by adding lime in order to reduce the possible problem of aluminum toxicity resulting from the excessively low PH (phosphorus) in the red soils. Vegetables and leguminous crops are grown between the hedgerows to improve the soil conditions. Our goal is not to create a forest, but to establish an agroforestry system that can provide a variety of outputs, and, at the same time, stabilise the soils and improve the overall soil nutrient conditions. The demonstration site is now one-year old, and it is too early to evaluate the successes and failures of the experiments conducted on that site. We have successfully produced a number of crops during the monsoon season and some of the fodder trees, particularly *Dalbergia sisoo*, were very successful colonisers during the first year of the experiment.

Conclusions

Understanding degradation processes is the key to successful rehabilitation of degraded lands and, as shown in this paper, deforestation, soil erosion, and soil fertility are important biophysical factors that need consideration. The following lessons have been learned.

Forest degradation in the watershed is not a process of gradual increase but has undergone at least two major cycles of deforestation and rehabilitation over the past 50 years. After each degradation cycle, the overall forest conditions decline and the recovery is never sufficient to reach previous carrying and production capacities. Major changes in policies were mainly responsible for the creation of the downward cycle.

Forest degradation cannot be measured effectively by forest cover but needs to include measures of biodiversity, biomass yields, soil fertility, and other site conditions;

The overall losses of forest land have been substantial and, combined with the changes in soil fertility and biodiversity, the current situation in the watershed is of serious concern in terms of maintaining production capacity and resilience.

Soil erosion is of key importance since agricultural expansion has moved onto marginal lands which are more vulnerable to degradation.

Farmers are doing an effective job in preventing runoff and minimising soil losses during low and intermediate sized storms. However, the large storms do most of the damage and are responsible for causing soil erosion losses that can reach up to 43 tonne per hectare in the steeply sloping dryland agricultural systems in the middle mountains. These marginal sites are most vulnerable during the pre-monsoon period.

Active afforestation programmes should focus on the degraded areas since they are the greatest cause of sediment transport. At the same time, afforestation in these areas is more effective if it is carried out in the context of agroforestry where nitrogen-fixing fodder trees are planted on terraces between agricultural plots. This provides protection against soil erosion and improves the soil nutrient conditions on these sites and has the potential to improve animal feed production.

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