Zeitschrift: Bulletin of the Geobotanical Institute ETH
Herausgeber: Geobotanisches Institut, ETH Zürich, Stiftung Rübel
Band: 65 (1999)

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DOI: https://doi.org/10.5169/seals-377825

Regeneration of vegetation on stabilising and eroding slopes in eastern Nepal: an evaluation 14 years after the first survey

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Summary

1 This paper reports the results of a resurvey of the vegetation of landslides and road cuts associated with a highway in eastern Nepal (Lamosangu-Jiri road).

2 The regeneration potential of the vegetation is generally high on stabilising and eroding slopes; revegetation takes place more readily at lower and middle altitudes than at high altitudes. In general, the vegetation has developed more vigorously than had been anticipated at the time of the first survey 14 years ago.

3 Land use like grazing, foraging and lopping of trees for fodder impairs regeneration considerably.

4 The rapid restoration of vegetation helps control the surface erosion which is induced through road construction and natural landslides. Especially when protected, the pioneer communities develop quickly to shrubland and young forests with a good stabilising effect.

5 The earlier fears of an adverse environmental impact of the Lamosangu-Jiri road have, to some extent, been mitigated by positive developments, e.g. forest protection, natural resource management, market supply, better house building standard and improved roof construction technology.

Keywords: environmental impact of road construction, erosion control, natural resource management, regeneration potential, vegetation-induced dynamics

Bulletin of the Geobotanical Institute ETH (1999), **65**, 43–58

Introduction

In the early 1970s, the Governments of Nepal and Switzerland established the Lamosangu-Jiri Road Project (LJRP) and the complementary Integrated Hill Development Project (IHDP) in East Nepal in order to promote economic and social development and to slow down the ecological degradation through improved utilisation of natural resources, generation of off-farm employment opportunities and reduction of the population growth. With the ongoing construction of the Lamosangu-Jiri road, one of the important concerns of the Project was to control erosion on the steep road cuts and natural landslides along the road. The problem was tackled with a combination of engineering solutions and an intensive planting campaign during the monsoon period 1982 (IHDP 1976–1985; Schaffner 1987b).

The problem of erosion is especially acute in Nepal for the following reasons (Kienholz *et al.* 1983; Messerli *et al.* 1993; Hofer & Messerli 1997; ICIMOD 1997):

- Natural erosion rates are very high because of the constant tectonic uplifting of the major mountain ranges and consequent downcutting of the river systems. The net result of these unrelenting forces are unstable slopes that cannot maintain their river-canyon form. Natural erosion occurs in several different forms, particularly rock failures, landslides, slumps, riverbank cutting and gullying.
- Pressure on limited land resources from the steadily growing population results in increased land degradation due to forest clearing, overgrazing, poor maintenance of marginal arable land and fire. The resulting accelerated erosion is mainly characterised by the loss of topsoil by sheet and rill erosion and gully building (Shah *et al.* 1998).
- Increasing activity in construction work, such as dam and road building, is also an important cause of land degradation.

Loss of topsoil by surface erosion is the direct result of heavy rains pounding unprotected soils. This erosion occurs in two stages: firstly the separation of the soil particles, and secondly their transport or removal by runoff. The cumulative effect is the impoverishment of the soil base. The major physical factors controlling the rate of erosion by water are (FAO 1983):

- Rainfall: the power of rainfall to produce erosion (i.e. its erosivity) is related to its amount, intensity and distribution; it is therefore a factor of climate.
- Vegetation and soil cover: vegetation interfers with the erosive force of the rainfall, and the amount of energy neutralised is directly proportional to the amount of land surface covered by vegetation. In addition, plant litter and roots protect the soil and improve its structure; in this way they enhance the infiltration rate and moisture storage capacity of the soil, and retard runoff. Vegetative cover also influences the effect of sun and wind on the soil surface and this in turn affects its erodibility (Shah *et al.* 1998).
- Soil: soils vary in their resistance to erosion (their erodibility). Part of this is inherent in the soil, and related to texture (mainly clay content) and the amount of organic matter, and partly depends on soil conditions and depth. A soil with a well developed and stable crumb structure will resist particle separation longer, and will also absorb rainfall faster, thus reducing the amount of destructive runoff. Runoff will also be reduced in proportion to the depth of a soil. It is evident that the more fertile and less degraded the soil, the greater is its ability to produce and support an effective vegetative cover.
- Topography: the gradient of a slope has a strong effect on the amount of erosion. Soil losses from steep slopes are much greater than from gentle slopes. Length of slope is also important. Surface roughness will retard runoff and decrease its quantity.
- Aspect: in some climates, and particularly when gradients are greater than 3%, there is a relationship between the amount of erosion and the aspect of a field or the geographical direction it faces.

During road construction in the LJRP, there was great concern on whether, how and how fast stabilisation would take place. One indicator of the stability of a slope is its vegetation cover; for this reason the regeneration dynamics of the natural vegetation along the road were observed from 1983 to 1986, shortly after road construction was completed. Records were taken on fixed transects through 35 study plots (landslides and road cuts) with different slope angles and aspects, ranging in altitude from 1100 to 2600 m (Fig. 1). The research was combined with studies in test plots on the relationships between plant

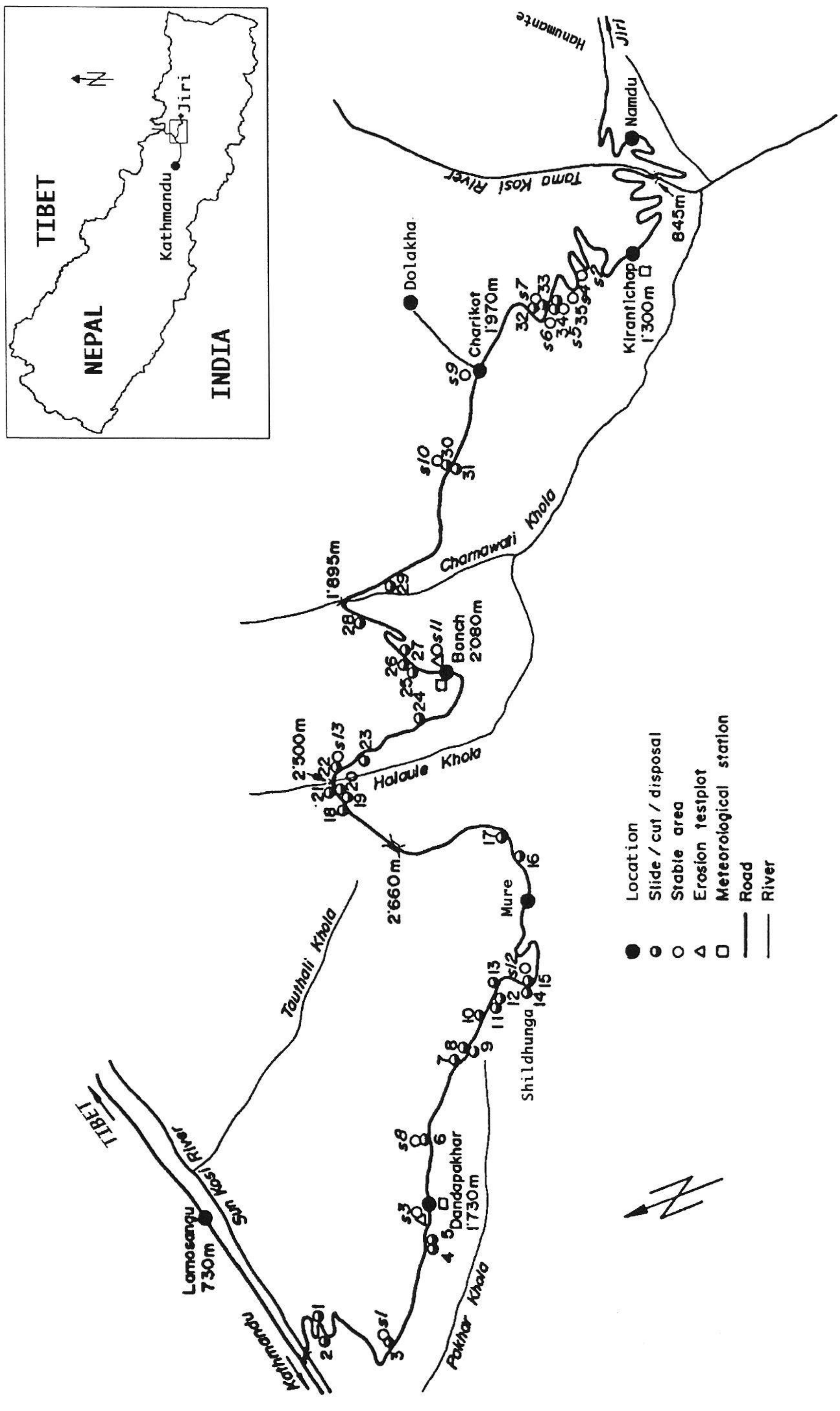

Fig. 1. Location of studied plots in eastern Nepal (first surveys 1983–1986, evaluation 1997; scale 1:180,000).

cover, runoff and soil loss on steep slopes. From this information an attempt was made to assess the influence of the different factors on vegetation development and soil loss. These included: meteorology, altitude, aspect, slope, soil, age of the slope/landslide, influence of man and livestock (Schaffner 1987a).

During a visit to Nepal in June 1997, I took the opportunity to drive along the Lamosangu-Jiri road. The impression of this inspection was overwhelming: Whereas twelve years ago the road was visible through the hills as a very conspicuous band between rough cuts and slopes, it is now difficult to detect among the terraced fields, shrublands and forest vegetation. This rapid revegetation of natural landslides and of areas damaged by road construction motivated me to carry out a short follow-up study. This report presents the findings of a resurvey of one third of the former study plots, grouped according to the four altitudinal belts that were defined in the first survey, which were based on the publications of Dobremez (1974, 1976) and Ohsawa (1977).

Geology, soil, climate and vegetation

Detailed information about the environment of the study area is given in Schaffner (1987a) and in the references mentioned there. Only a brief summary will therefore be presented here.

The eastern hills of Nepal belong to the young tertiary mountain ranges of the Himalayas which are still being uplifted. Three major rock types are found here: crystalline rocks (various gneisses), metamorphic sediments (phyllites and cristalline schists), and quarternary deposits (river deposits). Of the latter, the most important are sediments of low metamorphic grade. In many places weathering is very deep, which can be attributed to heavy cleavage and rock characteristics. A variably thick covering of loose detritus and scree conceals the bedrock, embedded in a silty, fine sandy matrix with practically no clay.

Nepal has a monsoon climate, with a pronounced rainfall maximum during June–September. Due to the irregular nature of the midland hills, the uneven topography and the extreme differences in altitude there exist different climatic belts (Dobremez 1974; ICIMOD 1996). Rainfall varies considerably according to the local topography; while temperature varies mainly according to altitude.

The monsoon climate promotes the development of a rich flora (Dobremez 1976; Ohsawa 1977). The records made in 1984 of some relatively stable areas, ranging from grassland to pasture, shrubland and forest, documented this well. Besides intensive land use pressure, there remain some indigenous (climax) forests in the region. In the lower subtropical belt (1100–1500 m) in areas with a northerly aspect we find a rich mesohygrophilous forest with *Castanopsis indica, Engelhardtia spicata, Indigofera dosna, Lyonia ovalifolia, Myrsine capitellata, Phyllanthus parvifolius* and *Schima wallichii.* On areas of southern aspect, xerophilous *Pinus roxburghii* forest prevails, with more or less dense herb and shrub layers depending on land use. In the higher subtropical belt (1500–2000 m), a mesohygrophilous forest with *Alnus nepalensis, Castanopsis indica, Gaultheria fragrantissima, Lyonia ovalifolia, Phyllanthus parvifolius, Quercus glauca, Rhododendron arboreum* and *Shima wallichii* is found. A large hygrophilous forest with a western aspect at around 2100 m is dominated by *Daphniphyllum himalayense,* but *Symplocos crataegoides* and *Alnus nepalensis* are abundant too. In addition to the well developed shrub layer with *Daphne bholua, Sarcococca pruniformis, Viburnum erubescens* etc., the herb layer is also very rich in species.

In the mesohygrophilous forest of the middle hill belt (2000–2600 m) on southerly aspect, *Quercus semecarpifolius* is the dominant tree, often heavily lopped and grazed beneath and thus in rather poor condition. Less accessible forests here have still a high diversity with *Daphne bholua, Litsea* sp., *Lyonia ovalifolia, Rhododendron arboreum, Symplocos* spp., *Viburnum erubescens* and *Viburnum stellatum.*

Alnus nepalensis occurs between 900–2700 m; it is a fast growing pioneer tree which quickly colonises disturbed ground and soils with low fertility. As it establishes easily on suitable sites, it was the preferred tree species for planting on road cuts and landslides in the LJRP.

Even when grazed regularly by livestock, the shrubland areas usually retain a high cover of plants. However, an interpretation of vegetation tables alone can be deceptive. The herb layer – although perhaps rich in species – is, with the exception of the neophyte *Eupatorium adenophorum* and a few other unpalatable plants, very short; in particular, the palatable species of Gramineae and herbs like *Arundinella nepalensis, Arthraxon lancifolius, Sacciolepis indica, Smithia ciliata, Sporobolus piliferus* and *Taraxacum officinale* etc. are diminutive. The same is true for regularly grazed grassland.

Methods

The 35 former study plots (landslides and road cuts) and 13 stable areas at altitudes between 1100 and 2600 m were assessed in a rough qualitative survey in 1997. One third of the study plots, i.e. 2–4 plots at each of the four altitudinal belts defined in 1983 (Dobremez 1974, 1976; Ohsawa 1977; Schaffner 1987a), were selected to collect limited quantitative data. The species present in the shrub and tree layers, and the main species in the herb layer were also recorded. Additionally, photo point monitoring proved to be a reliable method to get an impression of the vegetation development. The former transects were not recorded as the vegetation cover is now composed of several layers and a new survey would require a different methodological approach.

The records were compared with the data gained in 1983–1986. The changes were evaluated and discussed in view of their effect on slope stability 12–15 years after completion of road construction. Evidence drawn from this comparison was complemented by data from further publications (Ohsawa 1983; Panday 1990; Gilmour & Nurse 1991; Howell *et al.* 1991; INFRAS/Swiss Agency for Development and Cooperation SDC 1995) and by discussions with persons involved in development and environment.

Results

GROUP 1, LOW ALTITUDE

These plots are at low altitude (1100–1500 m), in the lower subtropical belt. The flora is rich in species, and the area densely populated; for an overview on the selected study plots see Fig. 1. The list of species is presented according to layer and abundance.

A comparison shows that the north-west facing study plot 2 (1180 m) was much more densely covered by herbs and shrubs in 1997 than in 1983–1986. A lush vegetation rich in species has established. The basic (shrubland) species group is present with e.g. *Cheilanthes farinosa, Gonostegia hirta, Imperata cylindrica, Indigofera dosna, Osbeckia nepalensis, Phyllanthus parvifolius* and *Pogonatherum* sp. However, the dominance of *Eupatorium adenophorum* is an indicator of disturbance and exploitation of this vegetation; in this densely populated region, land use pressure on uncultivated shrubland through grazing, foraging and lopping is high so that no forest can deve-

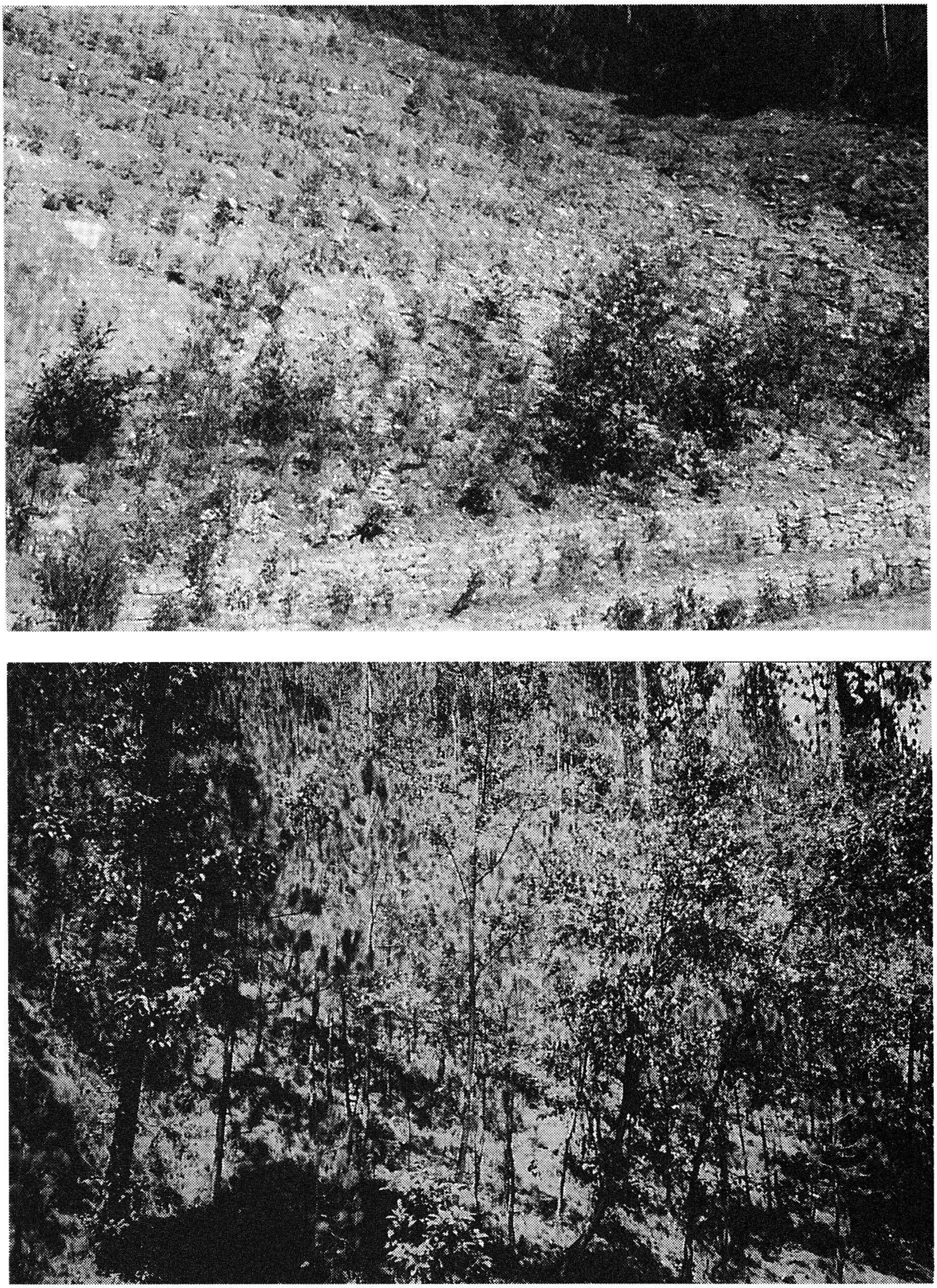

Fig. 2. Regeneration of vegetation on study plot 3, a landslide in Pinus roxburghii *forest at 1450 m; (a) 2.11.1983 shortly after road construction, (b) 10.6.1997.*

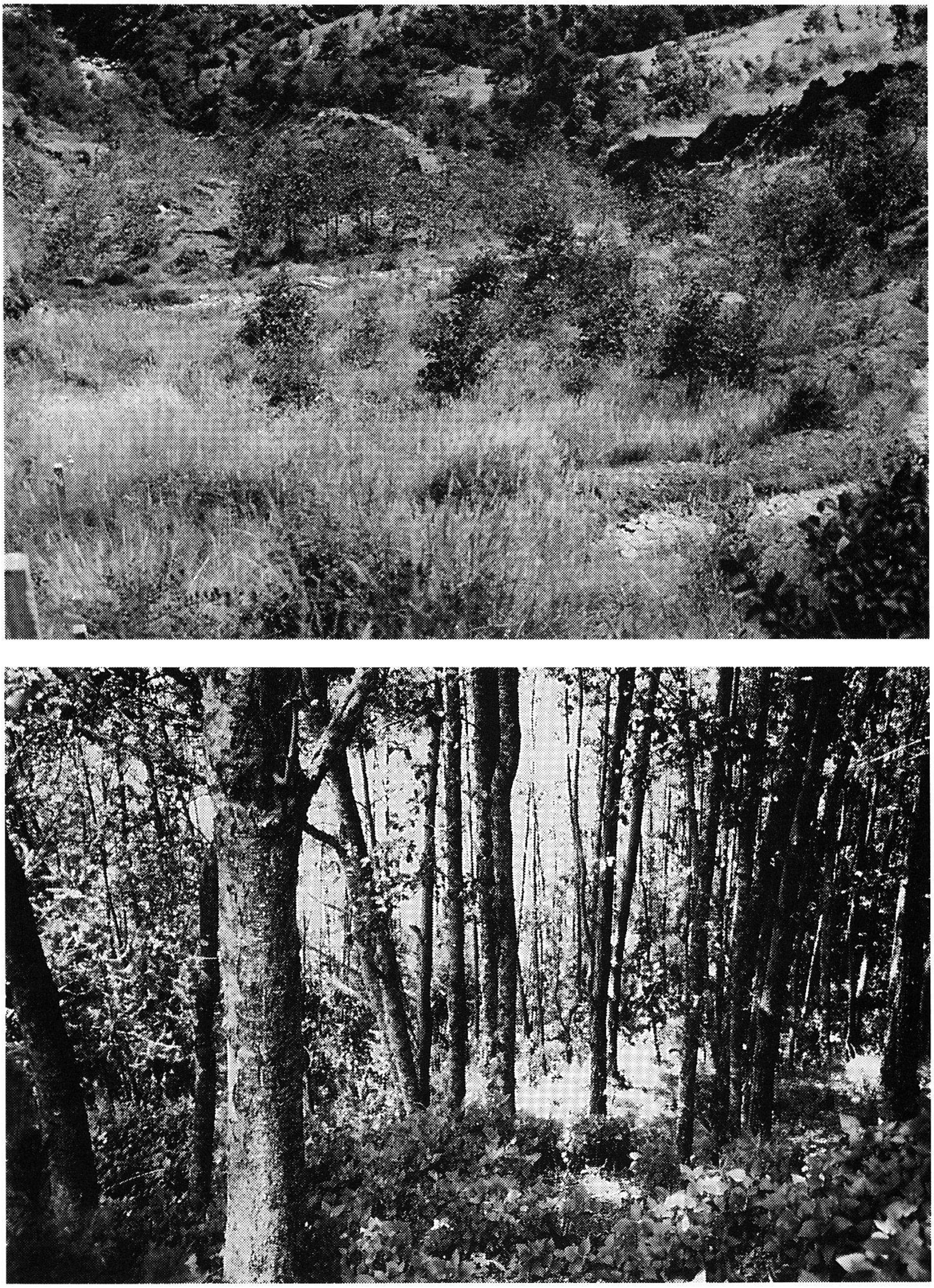

Fig. 3. Regeneration of vegetation on study plot 27 at 1975 m, a landslide which occurred in 1970; (a) 7.10.1983, (b) 10.6.1997.

lop. On plot 1 however, which has been fenced since 1982 and thus protected from grazing, young climax forest, with e.g. *Engelhardtia spicata, Lyonia ovalifolia* and *Schima wallichii,* has established.

Figures 2a,b show the development on a south facing plot 3 (1450 m) which lies in a well preserved xerophilous *Pinus roxburghii* forest, protected from grazing. By 1997, the steep slope was densely covered with young chir pines. Amongst the young trees, *Schima wallichii* recovers well and there are even a few young *Rhododendron arboreum,* although this is rather a low altitude for this species. *Alnus nepalensis* (planted on top of the breast wall in 1982) has had some stabilising effect at the base of the slide, but it grows poorly on this dry site. *Eupatorium adenophorum,* planted in 1982 as a first cover on the bare slope (Fig. 2a), is no longer important. Beneath the chir pines a dense grass layer has developed.

GROUP 2, LOWER MIDDLE ALTITUDE

These plots are at lower middle altitude (1600–2100 m), in the upper subtropical belt with a generally southern aspect; it is an area with intensive land use.

The south facing plot 6 above the breast wall of the road (1810 m) was a nearly bare landslide in 1983. By 1997 the dense shrub layer consisted of the pioneers *Eupatorium adenophorum, Hypericum cordifolium, Osbeckia nepalensis* and *Phyllanthus parvifolius.* The cultivated *Alnus nepalensis* has grown 10 m tall; *Schima wallichii, Lyonia ovalifolia* and a few *Eurya accuminata* grow well and, together with *Anaphalis contorta,* indicate the trend towards a more stable area. The observed regrowth demonstrates the high regeneration potential at this altitude despite the fact that the slope is not protected against grazing and pedestrians.

Figures 3a,b are photographs taken from the same place to compare the plot 27 (1975 m) in the years 1983 and 1997. This plot is the site of a south-east facing landslide which occurred around 1970 and, though not very steep, was still unstable in 1982; it was therefore protected by a fence after planting *Alnus nepalensis.* In the shade of the strongly grown alder (some higher than 10 m), the herb layer which was already well developed by 1983 could persist. The densely covered site with its straight growing pole trees gives the impression of now having stabilised.

The south facing plot 28 (1950 m), formerly an alarmingly unstable landslide above the road, has been stabilised, at first by constructing a breast wall, then by fencing and planting of *Alnus* at the foot of the slide, and finally by the vigorous growth of the herb and grass cover. The influence of grazing can be clearly seen; inside the fence there is a regular and dense herb layer, while outside the terrain is rough and *Eupatorium adenophorum* has established itself in the gaps formed by animals' hooves and is now dominating.

GROUP 3, HIGHER MIDDLE ALTITUDE

These plots are at lower middle altitude (1900–2200 m), in the upper subtropical belt to middle hill belt with a generally northern aspect.

The development of plant cover on plot 9 (north-east facing, 1990 m), a former steep and coarse rocky road cut, is striking (Figs. 4a,b). In 1982, when the road was built, some *Alnus* seedlings were established with difficulty on the plain lithosol. These plants have grown well, and some are higher than 10 m. The dense cover evident in 1997 is formed by a great diversity of young (climax) trees and shrubs, mainly *Rhododendron arboreum, Lyonia ovalifolia, Gleichenia gigantea* and many more. *Eupatorium adenophorum* could only establish at the foot of the steep slope which is disturbed by passers-by.

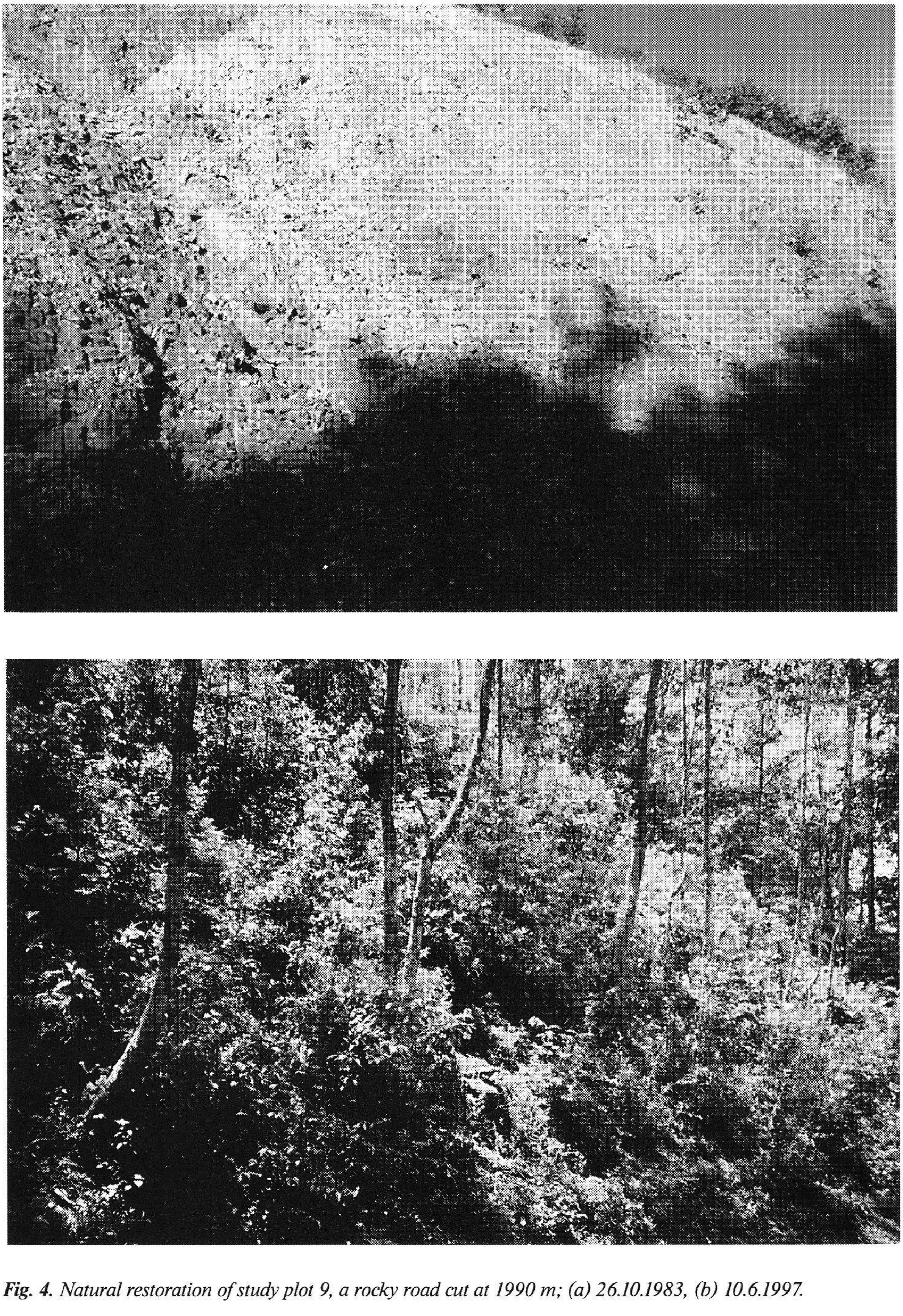

Fig. 4. Natural restoration of study plot 9, a rocky road cut at 1990 m; (a) 26.10.1983, (b) 10.6.1997.

Fig. 5. Regeneration of vegetation on study plot 14 at 2120 m, a landslide in Daphnipyllum himalayense *forest dating from monsoon 1978; (a) 2.10.1984, (b) 10.6.1997.*

Plot 14 (north facing, 2120 m) lies in a hygrophilous *Daphniphyllum* forest which was recorded in 1983 as rich in species; the regeneration potential here again proved to be very high, as can be seen in Figs. 5a,b taken from the same spot 13 years apart. The slide below the road, triggered by road construction during monsoon rainfall in 1978, is now lushly vegetated by a variety of shrubs and ferns, and from both sides climax forest trees and shrubs are pushing in.

In the same hygrophilous forest, a landslide was triggered by road construction in 1978 on the mountainside (plot 15, north-west facing, 2170 m). In 1982, an effort was made to stabilise the site by arch structures as well as by seeding and planting of *Alnus nepalensis.* On the shallow lithosol the *Alnus* trees grew rather thinly, but there is a dense spontaneous cover of young climax trees, shrubs and creepers like *Chambainia cuspidata, Gaultheria fragrantissima, Hypericum uralum, Lyonia ovalifolia, Rhododendron arboreum* and *Viburnum erubescens.*

GROUP 4, HIGH ALTITUDE

These plots are at high altitude (2300–2600 m), in the middle hill belt; it is an area with intensively used pastures and forests.

The regeneration on a valley side scree slope, study plot 19 (south-east facing, 2500 m), shows the growth of a rather fragmentary shrub layer with *Edgeworthia gardneri, Lyonia ovalifolia, Pteridium aquilinum* and *Rhododendron arboreum.* Even though obviously grazed, the herb layer became denser with, in particular, *Anaphalis contorta, Potentilla fulgens* and *Rubus nepalensis.* On the south-western part of the slope beneath the planted pine trees a herb and shrub layer was almost absent by 1997. The few planted *Alnus* trees did not grow well.

The very steep mountain side road cut of study plot 21 (south-east facing, 2530 m) was stabilised, thanks to the breast wall and to its steepness, for here no grazing is possible; however, the vegetation cover on this lithosol is not dense.

The long landslide in the mesohygrophilous *Quercus semecarpifolia* forest, study plot 22 (south-west facing, 2550 m, Figs. 6 a,b) seems to be stable now. However, it is grazed and the oak trees are still heavily lopped, and there is no sign of forest vegetation extending into the slide area.

Plot 23 (south-west facing, 2440 m) is on a steep valley-side scree slope where the steepness makes grazing difficult. Regeneration of young trees and shrubs (*Lyonia ovalifolia, Rhododendron arboreum, Rubus ellipticus*) is quite strong, but *Eupatorium* also grows abundantly.

Discussion

RECOVERY AND DEVELOPMENT OF THE PLANT COVER

The speed and vigour of vegetation development in the areas disturbed by road building is impressive. The potential for regeneration in this region has proved to be high. Herb and shrub layers have both developed well, and the following climax species have prospered: *Lyonia ovalifolia, Pinus roxburghii* and *Schima wallichii* in the lower and middle belt (1100–2200 m), and *Anaphalis contorta, Lyonia ovalifolia, Gaultheria fragrantissima* and *Rhododendron arboreum* in the high altitude belt (2300–2600 m). With trees and perennials establishing on the observed plots, the shift from slide communities towards more anchored plants is obvious. In 1986 it was thought that the development from bare ground to shrubland would take several decades; on most of the sites it has happened within a dozen years.

On the former bare landslides and road cuts the development from the bare soil to shrubland and even to young forest is quickly going on, especially on fenced and inaccessible slopes such as plots 3, 9, 27, 28 (Figs. 2, 3). On better accessible and therefore more disturbed slopes (e.g. by grazing) a development to open shrubland is taking place, as can be observed e.g. on plots 2, 28 (partly) and 19.

Although the records show a denser plant cover on plots 19, 21 and 22 in 1997 than in 1983–1985, regeneration here has been less successful. There are two reasons for this: firstly, these slopes lie at an altitude of about 2500 m; secondly, grazing has obviously had a strong impact (Howell *et al.* 1991). The pictures of plot 22 (Fig. 6) show very clearly that the *Quercus semecarpifolia* forest has not expanded at all into the landslide area. The slope here is grazed, and the oaks are still heavily lopped for fodder. On the steep and thus less accessible plot 23 at about the same altitude regeneration is better, suggesting that the weak regrowth of the other high altitude plots is due to grazing and a lack of parent trees because of lopping.

Generally, surface erosion induced through road construction or landslides has been controlled along the Lamosangu-Jiri road. The success of regeneration is due not only to the planting of trees (especially of well performing *Alnus nepalensis*) and the building of structures such as retaining walls and breast walls, but also to the high regeneration potential of the indigenous flora. The developing shrubland and young forests have successfully stabi-

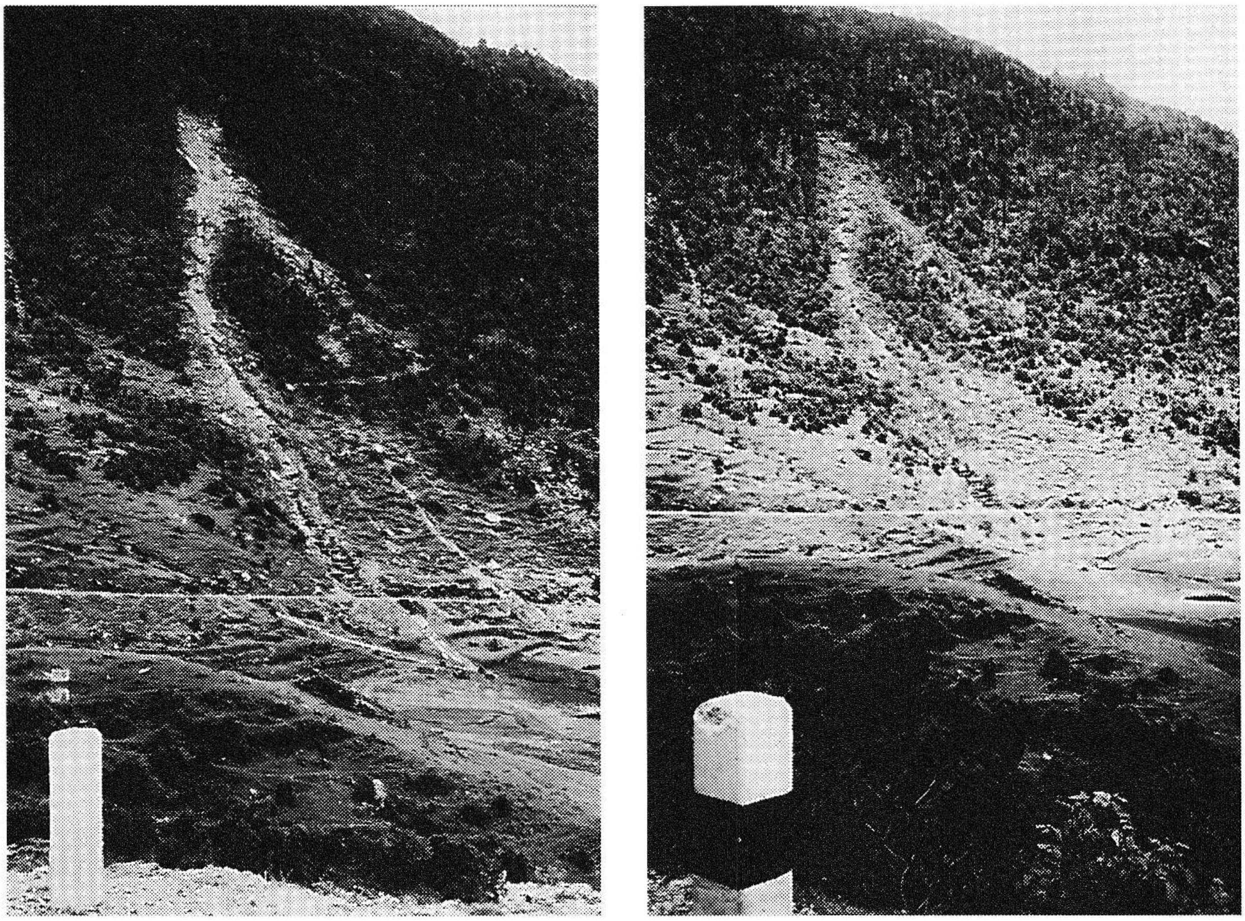

Fig. 6. Overview of study plot 22 at 2550 m, a landslide in Quercus semecarpifolius *forest dating from monsoon 1982; (a) 12.10.1984, (b) 10.6.1997.*

lised these sites. More research would be needed on whether and how much the plant roots are increasing the soil shear strength here, and thus how much the root system helps stabilize the more deeply seated slides.

Eupatorium adenophorum, a neophyte scarcely eaten by animals, is rarely found in protected or well managed plots. This corroborates the observation already discussed in Schaffner (1987a) that the so-called "killer of forest" (Nepali meaning of "banmara") has no chance to spread in sustainably used areas. However, *Eupatorium* does help to protect road slopes from at least topsoil erosion. As these areas should not be considered for use as pasture land, it is advisable to first promote non-palatable or grazing pressure resisting species, especially if full protection from grazing by watchmen or by fencing cannot be guaranteed.

Howell *et al.* (1991) express their reservations about the control of surface erosion by pioneer communities and shrubs along the Dharan-Dhankuta-Hile road in far eastern Nepal, and they recommend weeding between the planted (tree) seedlings. The climatic and geological conditions in those hills may be different from in the region of the Lamosangu-Jiri road. Here, there is no doubt that the pioneer community performs an important role in providing the first cover of the bare slopes and in producing suitable microclimate for succession. As a result the shrub layer soon develops to a nearly 100% cover on formerly exposed slopes. If weeding is done to promote planted seedlings, it must be practised with the utmost care so as not to disturb the consolidating site.

The observed high regeneration potential of the vegetation cover can be attributed to several circumstances. Firstly, despite intensive land use, plant diversity in shrublands and forests in the hills of eastern Nepal is still very high. Secondly, plant growth at the altitudes studied (1000–2600 m) benefits from the subtropical monsoon climate. Finally, in cultivated areas a rich seed source is available on the slope walls of the terraced fields of plant species well adapted to steep sites (especially of the herb layer).

Landslides that have occurred in cultivated areas can be stabilised by the farmers through recultivating or terracing. A good example of how rapidly this can occur can be observed on the "Urlini-landslide". The incident occurred in 1985, when a muddy flood destroyed a wide strip of paddy fields and several houses. By 1997 the event can be detected only with difficulty, and the whole slope has regained a balance similar to that of the much older terraces of paddy fields, which are skillfully maintained with the traditional knowledge of the farmers.

Some land that in the mid-eighties seemed to be abandoned or too marginal for cultivation has since been (re)cultivated. Such re-use of long-cycle fallow land was repeatedly observed, among other places, on a stable area (s 2; see Fig. 1) above Kirantichap, near a *Pinus roxburghii* forest at 1600 m, and on s 9 at Charikot, a former *Imperata cylindrica* grassland at 2050 m. These observations partly contradict the findings of the evaluation carried out by INFRAS/SDC (1995), that no land on marginal slopes has been newly cultivated.

FOREST *VS* SHRUBLAND

There is a gradual transition between forest, grazed forest, forested pasture land, shrubland and pasture land in the region studied (Ohsawa 1983). Generally, if a high vegetation cover exists composed of a diversity of native plant species (shrubs, trees and herbs), it is not correct to speak of "over exploitation". Forest management is "the ability to maintain a balance between the productivity of the resource and the harvesting for farming and household uses" (Panday 1990). The "multi-use" of forest in countries with self-subsistence obviously results in forms of forest vegetation different from those in western countries which are managed and established mainly for timber exploitation or as protective forests. Some forests, and especially afforestations, seem to be well protected. However, in the plantation "monocultures", more could be done by management towards increasing diversity and allowing natural regrowth to develop.

IMPACT OF THE ROAD: SOME OBSERVATIONS

I formed a general impression of a more sustainable land use in 1997 compared with the mid-eighties, or of a decreasing exploitation pressure. This was especially the case at lower and middle altitudes where the vegetation of pastures, shrublands and forests has generally recovered. After only a short field visit I cannot be sure whether this change is due to an improved management of natural resources. However, it could be one result of the development activities promoted by the Integrated Hill Development Project 1974–1990. It may reflect the afforestation efforts of the project, as more firewood and timber are now available. Furthermore, fuelwood for cooking is often substituted by kerosene which is more easily available as transport is now facilitated by the road. The improvement and introduction of fodder grasses and fodder trees also helps to preserve natural resources. Livestock now tend to be stall fed, and the animals are not allowed to roam freely. Consequently, even if fewer animals are kept (INFRAS/SDC 1995), more manure can be collected directly. This confirms the impression that there are now more compost heaps composed of manure and foliage to be scattered onto paddy fields before ploughing. Overall, there appears to be an increase in tree cover, not only in the study area, but in many parts of Nepal (Gilmour & Nurse 1991; Panday 1997).

The following impacts of the new road could be observed during and after construction: In the mid-eighties, the road was seen as a strong external interference, and was regarded as an "injury" to the people, villages, environment and landscape. The old porter trails along the road were abandoned and collapsed. New houses, mostly cheap, ugly, flat roofed buildings, were increasingly constructed along the road. The shifting of the centre of market places like Mure, Maina Pokhari, Charikot, Kirantichap, Namdu to the vicinity of the road soon became obvious. The result was a certain degradation of distant or unfavourably situated villages like Dolakha or Jiri market with less advantageous locations. The new accessibility of the large forests of Shildhunga, Hanumante and along the Tama Kosi river facilitated exploitation of timber and firewood.

In the longer term, it seems that the adverse influences of the road have decreased. Investments are taking place in more distant places too, e.g. maintenance of the well-built, old houses in Dolakha, new traditional houses are built off the road, a high number of houses now have strong roofs of stone slate or corrugated iron, and the building standard of the new houses has generally improved; all this indicates an increase in the general state of wealth. Some of the old market villages have recovered. For example, in Dolakha and Jiri the traditional Saturday market has been reestablished. The forests along the road seem to have accomplished a new equilibrium: besides some old parent trees and different age stages of the trees, a vigorous rejuvenation is taking place. In summary, the trends towards environmental degradation which prevailed in the 1970s and 1980s have been partly reversed (INFRAS/SDC 1995).

Conclusions

An overview of the more than thirty study sites and the qualitative and quantitative record of the plant cover on 12 chosen slopes and former landslides along the Lamosangu-Jiri road in eastern Nepal 14 years after the first surveys revealed the following findings:

1. An surprisingly rapid and effective restoration of disturbed areas has occurred. On the former bare landslides and road cuts the development from bare soil to shrubland and even to young forest is proceeding rapidly.
2. The potential for regeneration of the vegetation cover in this region proves to be high. Herb and shrub layer have developed well. The following plant species are growing strongly: the climax trees and shrubs *Engelhardtia spicata, Gaultheria fragrantissima, Indigofera dosna, Lyonia ovalifolia, Pinus roxburghii* and *Schima wallichii*, shrubland species like *Eupatorium adenophorum, Hypericum cordifolium, Osbeckia stellata* and *Phylanthus parvifolius* in the lower and middle belt (1100–2100 m); the climax species *Anaphalis contorta, Gaultheria fragrantissima, Gonostegia hirta, Lyonia ovalifolia, Rhododendron arboreum* and *Rubus nepalensis* in the high altitude belt (2100–2500 m).

3. The vegetation on undisturbed plots, mainly those protected by fences or not easily accessible, has generally recovered much better than on the unprotected plots. Grazing has clearly an adverse impact on regeneration.
4. In the forests of Shildhunga, Hanumante and along the Tama Kosi river, the steep slopes beneath the road are better preserved and have regenerated more rapidly than the more easily accessible slopes above the road where the forest is rather exploited.
5. As the slopes and cuts on the entire road corridor are well covered by vegetation, the successional changes postulated in 1986 can be confirmed. However, regeneration on the studied slopes has taken place more quickly than estimated: on rough bare ground, the succession from pioneer communities to shrubland or, at some places even to young forest, has taken place within only a dozen years.
6. Generally, erosion induced through road construction or landslides has been controlled along the Lamosangu-Jiri road in eastern Nepal. Much of this restoration is due to the high regeneration potential of the indigenous flora and its obviously stabilising effect at least on roadslopes and shallow slides.
7. More generally, the region appears to have overcome the feared adverse impacts of the road and various positive developments can be observed. From an environmental point of view the most satisfying of them is the protection of forests and the more careful management of the natural resources. This can directly be linked with the new road as various substitutions for natural resources have occurred (e.g. electricity for light and kerosene for cooking); in addition, the permanent as well as seasonal migration of people out of the area has reduced pressure on local natural resources. However, the improvements can also be linked with the growing awareness of Nepali farmers of the dependence of their households, farmland and livestock on forests and natural resources.

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Received 18 March 1999
revised version accepted 19 May 1999