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5. DISCUSSION

5.1. VEGETATION, REGENERATION OF VEGETATION AND ENVIRONMENTAL CONDITIONS

The rich flora of the Himalaya ist mentioned by POLUNIN and STAINTON (1984) among others - Nepal alone has some 6500 recorded species of seed plants. The high variation of the different types of flora is influenced by many factors. According to the above authors, altitude is the most important of these, followed by aspect and precipitation. In areas affected by the monsoon, the chemical composition of the underlying rock is not of prime importance; only a few species have definite preferences in these terms. The depth of soil and its ability to hold water during the dry season seems to be more important.

In the study area this wealth of flora is reflected in the extensive frequency tables of the stable areas and of the landslides and slopes. The above statements on influencing factors support the division of my plots into four groups mainly according to altitude plus an additional division according to aspect for those plots lying at "middle altitude".

In general, the monsoon climate of East Nepal has a strong positive effect on regeneration. Because of this and the floral variation and diversity, there is a high potential for vegetational regeneration in the subtropical and middle-hill belt of the study area. However, this potential is considerably weakened by the influence of man and animals: the clearing of the forests to obtain land for cultivation or pasture has greatly altered the original composition of the vegetation (NUMATA 1966, DOBREMEZ 1976, KOLLMANSPERGER 1977, POLUNIN and STAINTON 1984). The few forests surviving in the cultivated zone are much changed by cutting for firewood, lopping for fodder, and grazing of animals (PANDAY 1982). Frequent burning in some areas - carried out regularly to improve the grazing - makes regeneration impossible. Uncultivated land around the villages is almost always heavily grazed (NELSON 1980).

An impression of this may be gained by comparing the fenced testplot in Dandapakhar with the surrounding area (Figs. 3.2, 3.3). It must be mentioned that since the afforestation of the whole slope by IHDP in 1983, a watchman has been employed to prevent animals feeding there. In practice, if this is not done very consistently, a fence would be much more effective. On the other hand, a fence can be pulled down or goats can be lifted over it, both of which happen frequently. NEVILLE (1985) suggests the use of fertilizer in plantations where a watchman is employed, thus accelerating the seedling growth and shortening the period for which the watchman is needed. The best protection, however, is achieved if people are helped to understand the connection between over-exploitation and erosion (NELSON 1980).

All the above does not mean that no "stable" area exists. In spite of the strong adverse influence of man and animals a relatively stable vegetation typical of the exploited regions has developed. For example, the shrubland which covers wide parts of the study area, represented here best by stable areas s6, s7 and s10, seems to maintain a fairly constant floral composition and with its dense plant cover provides good protection against erosion. The testplot results at Dandapakhar demonstrate this fact well. Other examples of stable vegetation are the heavily lopped and grazed forests of *Quercus semecarpifolia* (stable area s13 and the anchors of plot No. 22, transects 30 and 31) or the mesohygrophilous forests of *Schima wallichii* such as those in stable areas s4, s5 and s8.

The "stability" of these areas is, however, relative: the flora is continuously being impoverished or changed because of over-exploitation. Although this matter was not intensively studied, it can be seen by comparing the stable areas s4-s7 of the Mati-region. No. s4 is fairly representative of the small remains of a mesohygrophilous forest rich in species. No. s5, lying in the area adjacent to No. s4, can still be called forest, but is exploited: the trees are lopped and animals feed there occasionally. Nos. s6 and s7 next to it are frequently grazed and have been reduced to shrubland with *Eupatorium adenophorum* dominating. This plant has invaded Nepal from outside (BANERJI 1958), is scarcely eaten by the animals and has thus spread over all pasture-land.

This type of impoverishment can also be shown by comparing the stable areas s1 and s2, both situated in *Pinus roxburghii*-forest. No. s2 is often burned and regularly grazed; no shrub-layer is able to develop, and the herb layer is relatively poor with some *Gramineae* dominating. In No. s1, however, burning, grazing and firewood cutting has not been allowed since 1982 (the last burning took place in 1980, after a protection of eight years, GRUENENFELDER 1980a). The rapid development of a

shrub layer is striking and the herb layer is very rich in species.
Lack of regeneration is much more severe in the unstable areas of landslides - natural or man-induced - and slopes. Once the plant cover is removed the fertile soil is quickly washed away by the very heavy rainfalls of the monsoon. The animals - searching for every green leaf in the dry season - loosen the remaining soil with their feet, and this loose soil is also washed away during the next monsoon. Only meagre development of plant cover is thus possible.
One way of solving this problem is protection of the vegetation (NELSON 1980). However, as mentioned above, real protection cannot take place without the co-operation of the people. That such co-operation is possible has been proved in the Pinus roxburghii-forest of stable area sl and in many afforestations of IHDP (GRUENENFELDER 1980a, NEVILLE 1985), but it is not easy to achieve. In this connection the "Chipko Movement" ("Embrace the Tree") should be mentioned, a movement started in Northern India to protect forests from commercial felling (SHIVA and BANDYOPADHYAY 1986). Even if not directly applicable to the conditions in Nepal, it shows that people can become aware of the problem of ecological stability.
Nobody feels responsible for the "no man's land" along the Lamosangu-Jiri road. The animals are usually driven along the road to their pasture-grounds and they feed on whatever is edible along the slopes of the road. To avoid this, fences have been built on very unstable slopes (plots 1, 4, 10, part of 27, 28). The plant regeneration on No. 4 (transect 8) was indeed much more advanced than on No. 5 (transect 9, unprotected) nearby; No. 10 (transect 15) was in much better condition than No. 11 (transects 16-18, unprotected: the different exposition has certainly had some influence too); transect 36 of No. 27 lies in the unprotected part of the landslide and had a lower increase of plant frequencies over the three years of observation than transect 37 which is in the fenced part (additionally planted with Alnus nepalensis and technically stabilized in 1981).
A second possible way to ensure better regeneration on landslides and slopes is the replanting of species that are not eaten. Alnus nepalensis was thus frequently planted or sown directly along the road. This tree combines valuable attributes: it is a pioneer tree able to bind nitrogen, i.e. it grows easily on rough and unfertile ground; it grows quickly (nearly 1 m per year) and roots deeply; it can be easily raised in

nurseries (GRUENENFELDER 1980b); it grows naturally at elevations from 800-2700 m a.s.l.; and last but not least it is generally not eaten by animals. The trees planted grew extremely well. For long stretches of the road this alder shades the slopes and enables a herb layer to develop underneath.

Eupatorium adenophorum was also planted as a cover for the slopes. It too combines many attributes: it grows well on poor land; its evergreen branches cover the soil well; it propagates without problem and it is not eaten by animals. But this species, being a weed, was not used on a large scale because it was opposed by some agronomists in IHDP (GRUENENFELDER 1980a). The Nepali name for Eupatorium is "banmara", which actually means "killer of forest". However, on the testplot in Dandapakhar Eupatorium tended to disappear while other plants thrived once the slope was protected. In my opinion, in unprotected areas "banmara" can only spread widely after the forest has been killed and competition from other plants has been reduced because of overexploiting, e.g. overgrazing. Equilibrium occurs if competition is made possible by protecting the other plants. Thus the name "killer of forest" is not, in fact, justified. A cover of Eupatorium along the road, on the slopes which are by no means considered as pasture-land, could thus be an excellent protection against erosion and grazing.

GREENHILL (1979), after two trial-seasons on landslides in the Bagmati Watershed Project, suggests planting Pennisetum purpureum and Desmodium spp. with reference to the fodder value of these species. But here too the question of priorities arises: A regeneration with fodder species draws the cattle and goats to the place and a fragile young landslide has no chance to regenerate if not strictly protected. Therefore it is much more advisable to first plant non-palatable species to let a slide regenerate and stabilize. After this process it might be possible to supplement plants with higher fodder value.

Regeneration starts with the micro-climate (KOLLMANNSPERGER 1977). By planting and protecting a new vegetational cover on bare slopes, a more balanced micro-climate develops and a greater variation of species will establish themselves. In this respect too, the planting of Alnus along the road has a positive effect.

5.2. DEVELOPMENT AND SUCCESSION

It is obviously difficult to state with certainty a succession after only three years of phytosociological observation (see ref. in KRUESI 1981). Too many factors interfere. Besides man and animals, one of the strongest influences is meteorology, and this in particular showed unusual extremes during the years of the study (IHDP 1976-1985, Fig. 4.39). In order to get a wider time range, the attempt was made to compare the vegetation of landslides of different ages. This too proved to be problematic, as other site factors never fully correspond. KRUESI (1981) suggests the use of phenological data for a better recording of succession in short term research.

Changes in the vegetation are represented in the ordination graphs. It would be dangerous, however, to assert a succession simply by interpreting these graphs: an anchor section might also change over three years and thus on the graph show a trend in a certain direction. It might be more reasonable to state a development trend than an actual succession.

A certain development is, in fact, visible, best shown by the increasing plant frequencies for practically all of the slide and transition sections (Fig. 4.6). The visual impression during the three years of observation definitely proved that plant cover became denser. The appearence of perennials and trees in slide or transition sections indicates obviously a development towards a more stable site since a still moving or disturbed ground would not allow them to settle.

In this connection the ecological studies of the Japanese expeditions should be mentioned. Forests, grasslands and weed communities of eastern Nepal were described and analysed in terms of their distribution, structure and dynamics (NUMATA 1983). The floristic composition of the grassland vegetation of the Arun-river region studied by TSUCHIDA (1983) is at 1100-2600 m a.s.l. quite similar to the composition in the more covered plots and the grasslands of my study; the unpalatable communities, which were often found in unmanaged grassland and the composition of the shrub-type plots are comparable to the shrubland occurring in our region. TSUCHIDA also states the general grassland succession at the same altitude as follows: Grassland-communities change into shrubland (dominated by <u>Eupatorium</u>, ferns, <u>Ageratum</u>, <u>Artemisia</u>, <u>Anaphalis</u> etc.) and progress through shrub communities (dominated by Eurya, Maesa, Osbeckia, etc. at lower altitude and Rubus, Rhododendron, Viburnum, etc. at higher altitudes) towards warm temperate forests such as Schima, Castanopsis, etc. These findings are to some extent covered by my observations: the Mati-region e.g., mentioned above (Chapter 5.1, Fig. 4.19), could easily be interpreted as grassland succession in the terms of TSUCHIDA. But there I prefer to state an impoverishment and continuous degradation of the floristic composition due to human influence, a process called "retrogressive succession" by TSUCHIDA.

OHSAWA (1983), another member of the Japanese group, gives some hints on dynamic structure and successional stages of forests in the different altitudinal zones, based on three ecological expeditions to the far eastern part of Nepal. He, too, concludes that human activities, including grazing by domestic animals, tree cutting, and fires, have considerable effect upon species composition and structure of the Himalayan forest. OHSIWA observed that on steep slopes, where grazing is difficult, an intact forest has a better chance of survival. It could be inferred, therefore, that a plant society on a former landslide has a chance to develop to a climax, provided protection is granted and a certain stabilization can take place.

5.3. METHODS

The method of stating plant frequencies by laying a fixed transect is efficient and yields quite accurate results (see Ref. in RIPPSTEIN 1985). It registers the increase in the different species in a plot quite reliably even if it gives no information as to the number and the size or age of the species occurring.

To some extent the mathematical processing generalizes the records as it reduces the frequencies, given from 0-100%, to a scale from 0-9 only.

With reference to the question of recording not only the presence per square of a species but also the number of each species (abundance) and in addition noting size or age, I think that for the present study the method used was satisfactory except perhaps for the anchors, rich in species. Here it might not be possible to assess the manifold flora by

just laying a line. But in this case the recordings of the stable areas give an additional idea of the anchor-flora of the different groups.
Some criticism may arise with regard to the soil research performed. With laboratory analysis of only the upper layer of 20 cm and determining the soil characteristics only by augering, the results may not be very accurate for many of the characteristics (Guidelines for Soil Survey and Land Evaluation in Ecological Research, UNESCO 1986). But with the backing of the detailed survey of ESPINOSA (1974, 1975), I decided not to dig soil pits.
When deciding about an erosion model the one used by HURNI in his research in Ethiopia (SCRP 1984) was chosen. This model is well worked out and adapted for a country with similar conditions to Nepal. MORGAN (1981) is sceptical about studies which concentrate on measuring the rates of soil loss under different plant covers and compare them with those measured on bare ground. Based on the results of HURNI I do not think MORGAN's criticism is justified with regard to the erosion model applied in Ethiopia and in this study.
The weekly weeding of the bare testplots probably increased the soil loss slightly, even when after the first clearing there were mainly seedlings to remove. By choosing this method the high regenerating power of such plots was not considered. Digging off the root-layer before the start of the rains could help, but this might disturb the composition of the soil. As a last resort, although reluctantly, herbicides could be used. After all, the disturbance of the soil by weeding can possibly be compared with that of grazing animals on unprotected slopes.

5.4. STABILIZATION VERSUS EROSION

Stabilization of landslides and slopes by plant cover is a much discussed and urgent topic at present. An awareness of the problem has resulted in numerous studies on erosion being carried out. It is stated by different authors that plant cover has a stabilizing effect, by balancing the waterflow and preventing erosion (i.e. SINGH et al. 1967, DONNER 1972, MULDER 1978, NELSON 1980, diff. Reports in TINGSANCHALI and EGGERS 1981, HURNI 1982, HURNI in prep., LAUTERBURG 1985, LAUTERBURG and MESSERLI in prep.).

The problem of erosion and stability of slopes has been investigated by some projects in Nepal (Ref. in LAUTERBURG 1985). FETZER (1977), in his study of the north western mountain ridge of Kathmandu valley, states that the main causes of soil erosion are the highly erosive rainfall characteristics (erosivity), the extreme vulnerability of the soils to erosion (erodibility) and the steepness of the slopes. He suggests to reduce these by building terraces and covering the soil with cultivation.

The Integrated Watershed Management Project (IWM) near Pokhara, under the Department of Soil Conservation and Watershed Management, has already contributed notable research-work concerning erosion problems. In a general basic study an empirical attempt to model the Universal Soil Loss Equation for that region was made (JAHN et al. 1979), since USLE is not directly applicable (IWM 1980). The high erosivity of the rainfall is stated. It was found that the soil loss is very high in early monsoon (IMPAT 1981, GUPTA 1981, CARSON 1985). LABAN (1978) specifies the minimum soil loss with 1-10 t/ha per year; on over-used lands (forests/grasslands) a soil loss of 20-50 t/ha is estimated. This may increase locally to 200-500 t/ha per year. A well maintained grass/forest cover can be expected to reduce soil losses by a factor of about 9, when compared with overgrazed grassland (IMPAT 1981).

The data measured in my testplots are comparable with the IWM data. The highest soil loss was generally recorded during the early rains before and at the start of the monsoon, with a second peak during August (with much rain of high erosivity) in Bonch. The difference in the amount of soil loss and runoff resp. between a bare and a plant-covered plot is striking. The soil losses of the overgrown plots in Dandapakhar with 3 t/ha (1984) and 0.5 t/ha (1985) and in Bonch with 4 t/ha (1985) are low (presumalby due to protection) if we consider that a reasonably tolerable soil loss of 10-20 t/ha per year is given for well-managed agricultural or grazing land (LABAN 1978). For the bare plots the loosening of some soil by regular weeding may be equated with the disturbance by grazing animals on unprotected slopes. The losses are high for Bonch (on weathered soil) with 67 t/ha in 1985 and Dandapakhar (on dense stone cover) with 16 t/ha in 1984. The low soil loss on the bare plot at Dandapakhar in 1985 with only 5 t/ha may be related on the one hand to the fact that, due to the wooden planks, no soil was able to invade the plot from above, while in the first year of the research much

soil was already washed out. On the other hand the lower soil loss in the second year of observation could indicate a certain trend towards stabilization.
The fact that the plots were protected has without doubt influenced the results. To eliminate this influence, the fences and planks could be removed during the dry season and thus open the place to grazing animals. The regeneration of the plots by plant cover would certainly slow down and the soil loss on the covered plots would presumably increase.
Since of the erosion-influencing factors (rainfall intensity and duration/soil/percentage of slope/vegetation), only vegetation can be controlled (SINGH et al. 1967), by all means to improve the conditions for an undisturbed development of a vegetation cover in fragile areas should be tried.
In order to get a certain stabilization more rapidly, natural regeneration can be supported by different measures such as technical stabilizations and the above-mentioned protection or replanting (SCHIECHTL 1980, GEYIK 1983). Considerable effort along these lines was made on the Lamosangu-Jiri road (GRUENENFELDER 1980a, SINGY 1982, SCHLATTER et al. 1982, SCHAFFNER 1985, NEVILLE 1985). Besides the numerous constructions to prevent erosion, great emphasis was laid on regenerating the plant cover on the slopes along the road. The planting of Alnus and Eupatorium is discussed above. They are by far the most promising measures there.
Point-turfing (placement of grass sods) was also carried out on different slopes of the Lamosangu-Jiri road. On slopes with an inclination of less than 75%, planting of Cynodon dactylon-sods was successful (GRUENENFELDER 1980a), and above 2000 m Pennisetum clandestinum developed well; both of these Gramineae are able to resist very high grazing pressure (NEVILLE 1985). The respective plots studied (Nos. 13, 17, 25, 30, 33) do not show a very good development, presumably mainly because the sods were taken from any grassland containing species not especially suitable as pioneer plants on poor soil. The steep incline of the slopes may render their regeneration difficult too. It often happens that the sods remain like small islands scattered over the slope without the plants spreading over it significantly. The soil between the sods is largely washed away and regeneration is thus slow.
Some sowing trials were made along the road and on some plots an adapted technique of hydroseed was applied and a kind of mulching by covering the seeds with Eupatorium twigs and wire netting was tried out (SCHLAT-

TER et al. 1982, BOLL 1983), an erosion control technique also introduced by KRAYENHAGEN (1980). With the exception of Alnus-seeds, these trials did not prove very successful, partly - being unprotected - due to grazing, partly to washing off by the heavy rains of the early monsoon. In any case the expense was not worth the result; three years later there was no measurable difference between a treated and an untreated slope.

Some hope was placed in cuttings of different species. Viburnum erubescens showed promising growth at first. But after some years only a few sticks remained on the slopes along the road, most of them dried up. The majority have been torn out by people passing by for some purpose. Populus monilifera cuttings, recommended already by STEBLER (1970), are promisingly fast growing if planted in good soil. But this restricts their use to a few places along the road.

In planting or sowing trials with other species, special attention must be paid to deep-rooting perennial plants with a good covering effect. They should also not be fastidious about soil (UPHADYAYA 1978). The following species, which partly meet these conditions, showed to some extent a good natural development in the studied plots of the lower and middle altitudes: Hypericum cordifolium, Osbeckia nepalensis, Phyllanthus parvifolius, Gonostegia hirta, Polygonum spp., Chrysopogon aciculatus, Cynodon dactylon, Pogonatherum sp. In the middle and higher altitudes Artemisia sp., Centella asiatica, Hemiphragma heterophyllum, Lycopodium clavatum (on wet slopes only), Arundinella hookeri (very strong roots) and Hemarthria compressa developed notably well. It might be worth carrying out more detailed revegetation trials with a selection of these species.

5.5. CONCLUSION

With its specific geology Nepal is bound to have a great number of unstable areas (SHRESTHA 1980, CARSON 1985). The still occurring uplifting of the Himalayas, the strong downcutting of the rivers, soft geological materials, the weight of vegetation and soil becoming too much (especially in excessive monsoon rains) to hold on long and steep slopes -

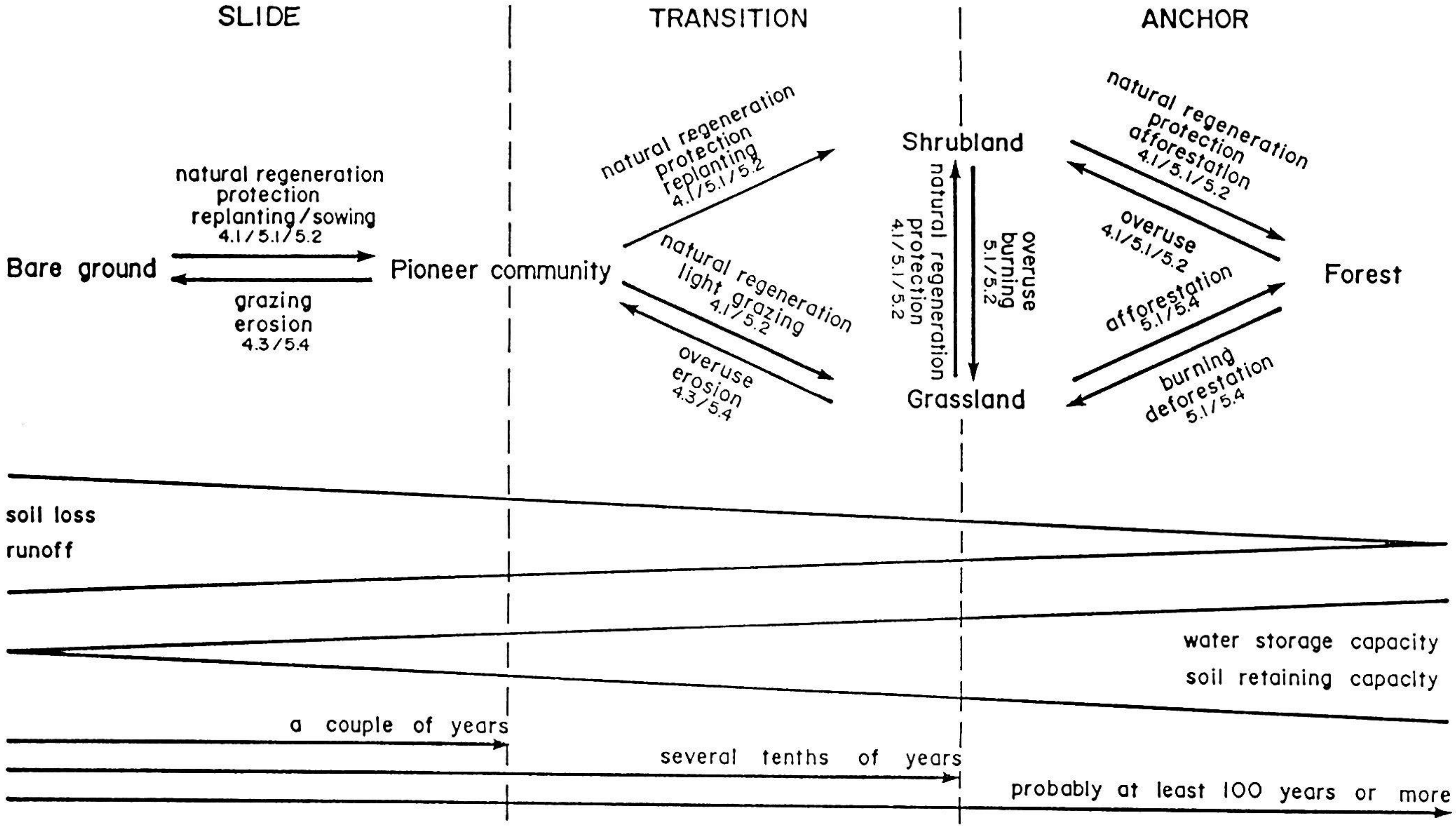

Fig. 5.1. Vegetation-induced dynamics on the studied plots (compare also figures in TSUCHIDA 1983)
Abb. 5.1. Vegetations-abhängige dynamische Vorgänge auf den Untersuchungsflächen (vgl. auch Abb. TSUCHIDA 1983)

these are some factors which influence the stability of a region strongly. Thus only a small part of the occurring landslides are man-induced (DONNER 1972, LABAN 1979). Considering the perhumid conditions of the monsoon climate of eastern Nepal, the question may arise as to whether real stabilization on steep slopes can actually take place. This question might be justified in the "naturally" fragile areas. But with the increasing pressure on marginal land and construction of roads etc. the man-made damages are advancing (NELSON 1980), and here measures can be taken to prevent or repair the destructive forces at work.

One indicator of the stability of a slope is the condition of its vegetation cover (FAO 1983). It is obvious and prove that when this cover is damaged or removed the diverse climatic factors affect the soil. The heavy rainfall during monsoon with its notable erosivity is the strongest factor. To reduce the high soil loss and runoff in crucial regions, first priority should be given to protecting existing vegetation and to replanting or afforesting bare slopes, whether landslides or technically created cuts.

When planting damaged slopes, it is advisable to first use non-palatable or grazing-pressure resisting species, especially if full protection of the area cannot be guaranteed. In this way it could be prevented that any young plant cover is grazed immediately after sprouting. After a certain appeasement of the slide - possibly supported by technical stabilizations - it is still early enough to introduce fodder species.

Figure 5.1 tries to show the vegetation-induced dynamics on eroding and stabilizing steep slopes in eastern Nepal.