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Kapitel: 4: Results

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4. RESULTS

4.1. VEGETATION

4.1.1. Landslides and slopes

The consequence of the diversity of site factors of the study area - especially the wide range of altitude - is a high vegetational heterogenity. A division of the plots into groups was therefore indispensable. Ordination and cluster analysis of the last survey (Sept./Oct. 1985), processed independently for the sections anchor, transition and slide (Figs. 4.1-4.6), showed a clear separation of a "high altitude group" and a fairly good separation of a "low altitude group". At the middle altitude other site factors than the altitude interfer. Among these the aspect seems to influence the vegetational composition noticeably. The following four groups were thus defined:

Group 1. Low altitude.
Plots 1-3 (transects 1-7) lie between 1100 and 1500 m in the lower subtropical belt (DOBREMEZ 1974a,b). Plot 1 and 2 have about the same altitude and both have a north-western aspect; plot 3 lies about 200 m higher and faces south (Fig. 4.7).
The anchor of plots 1 and 2 (transects 1-6) are composed of a mesohygrophilous forest with Schima wallichii, Castanopsis indica and Engelhardtia spicata. The trees and shrubs of No. 2 are frequently cut for fodder and firewood, and cows and goats feed there. The forest is thus reduced to shrubland. The anchor of No. 1 is in better condition due to protection by a fence built in 1982 by LJRP to give the severe landslide a chance to stabilize.
Plot No. 3 (transect No. 7) is situated in a xerophilous forest with mainly Pinus roxburghii, scarcely any underwood and a very short herb layer. To give the forest a chance to regenerate no pasturing or cutting of firewood has been allowed since 1982 (this interaction is to last for 7 years); but grass cutting is permitted. Thus the undershrub is steadily developing (for anchor of No. 3 see also stable area No. s1, for comparison stable area No. s2, Figs. 4.8, 4.9).

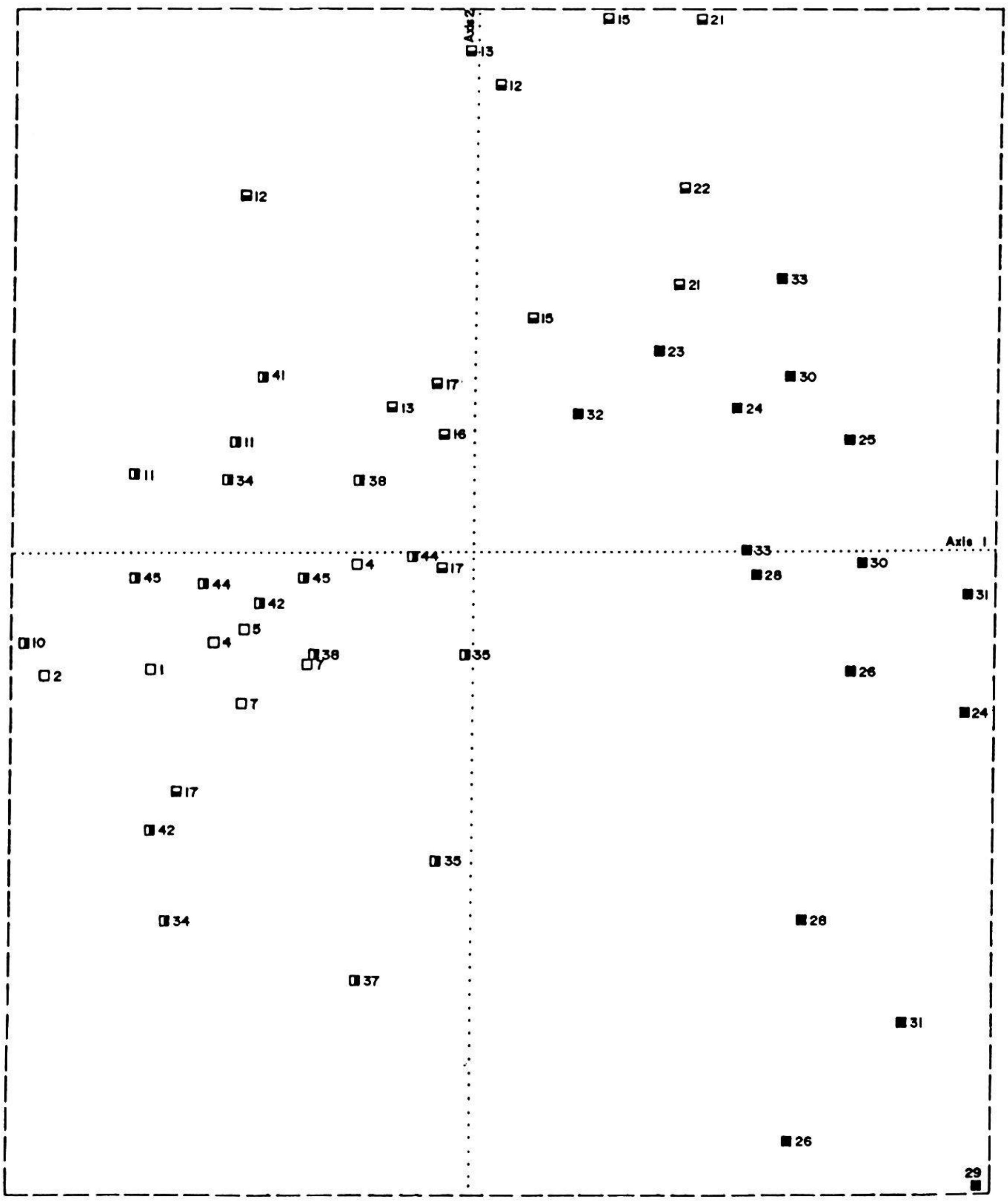

Fig. 4.1. Ordination of anchor sections, last survey (Oct. 1985): Separation of four groups

Abb. 4.1. Ordination der Anker-Sektionen, letzte Aufnahme (Okt. 1985): Einteilung in vier Gruppen

- ☐ 4 = anchor group 1 with transect No.
- ◧ 37 = anchor group 2 with transect No.
- ⬓ 17 = anchor group 3 with transect No.
- ■ 29 = anchor group 4 with transect No.

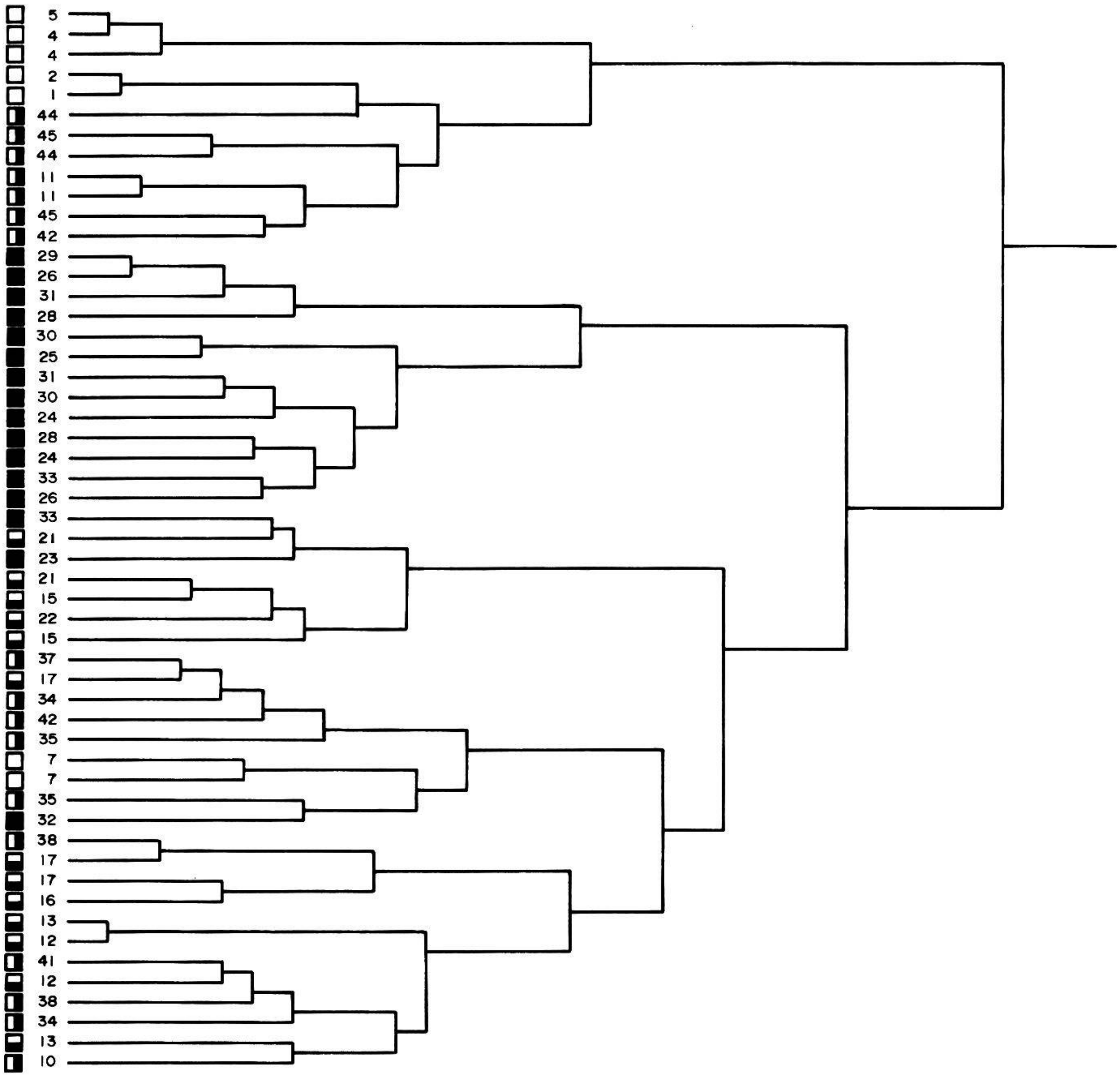

Fig. 4.2. Cluster analysis of anchor sections, last survey (Oct. 1985): Separation of four groups (for legend see Fig. 4.1)

Abb. 4.2. Dendrogramm der Anker-Sektionen, letzte Aufnahme (Okt. 1985): Einteilung in vier Gruppen (Legende siehe Abb. 4.1)

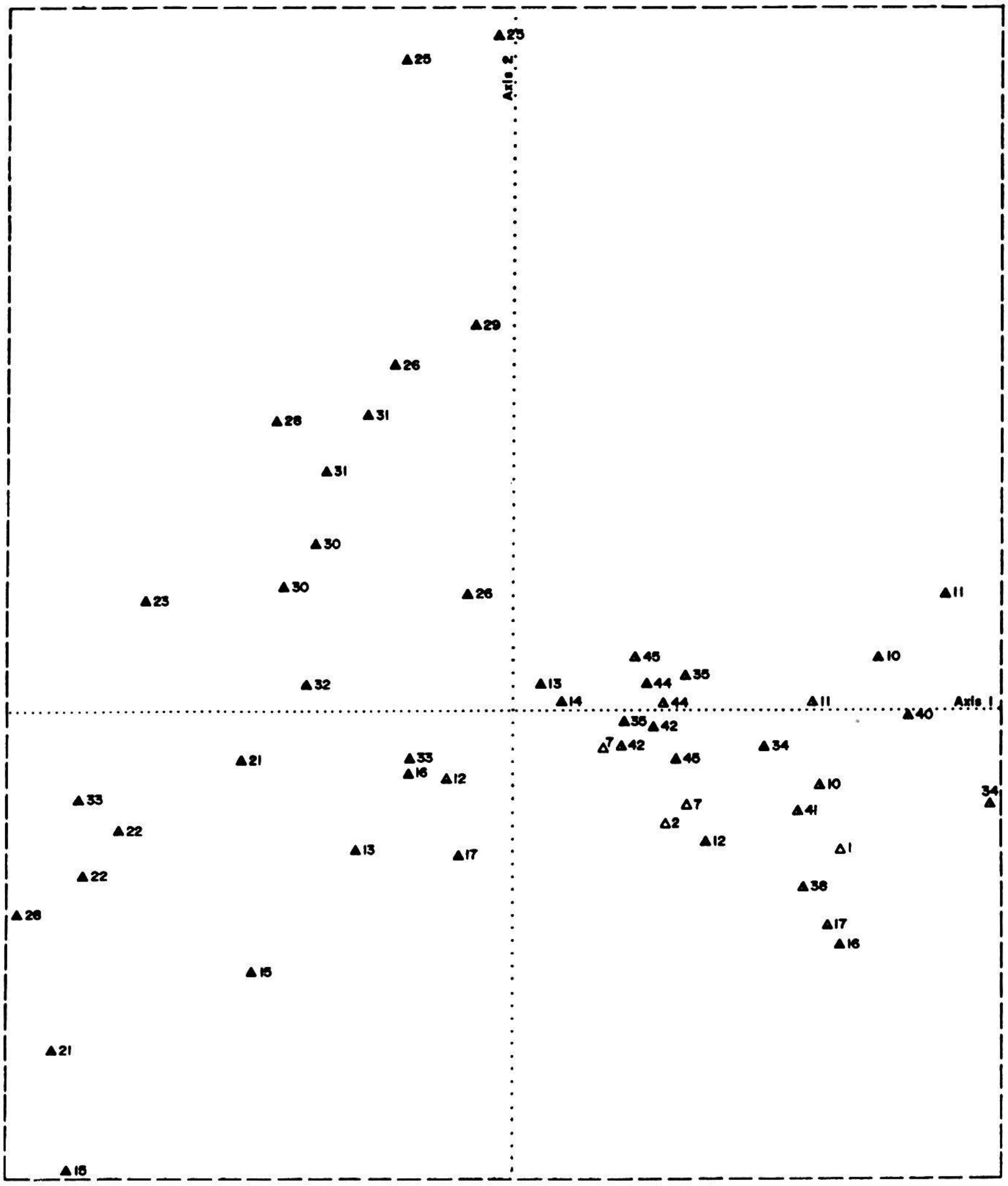

Fig. 4.3. Ordination of transition sections, last survey (Oct. 1985): Separation of four groups

Abb. 4.3. Ordination der Uebergangs-Sektionen, letzte Aufnahme (Okt. 1985): Einteilung in vier Gruppen

△ 7 = transition group 1 with transect No.
▲ 45 = transition group 2 with transect No.
▲ 12 = transition group 3 with transect No.
▲ 26 = transition group 4 with transect No.

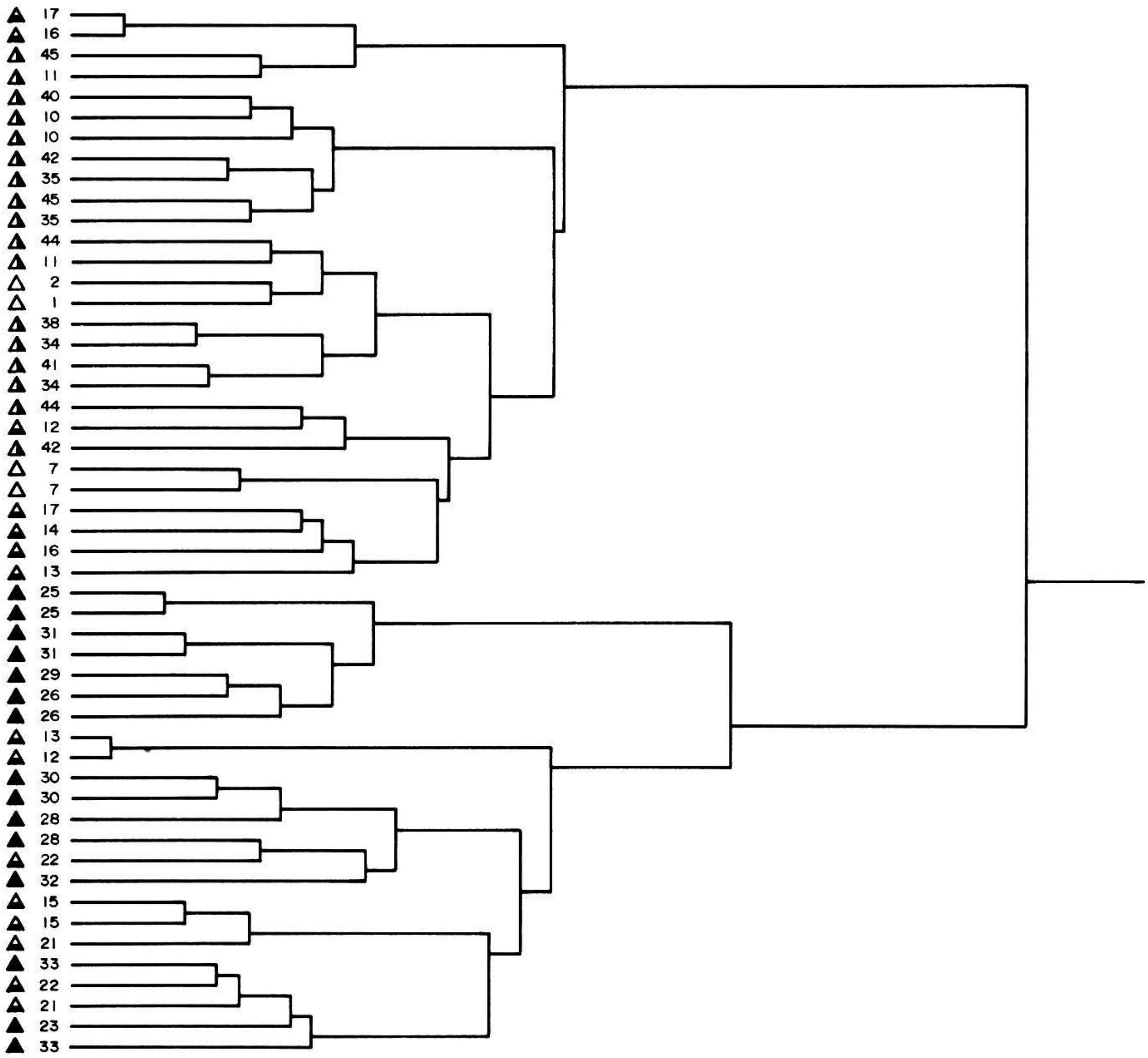

Fig. 4.4. Cluster analysis of transition sections, last survey (Oct. 1985): Separation of four groups (for legend see Fig. 4.3)

Abb. 4.4. Dendrogramm der Uebergangs-Sektionen, letzte Aufnahme (Okt. 1985): Einteilung in vier Gruppen (Legende siehe Abb. 4.3)

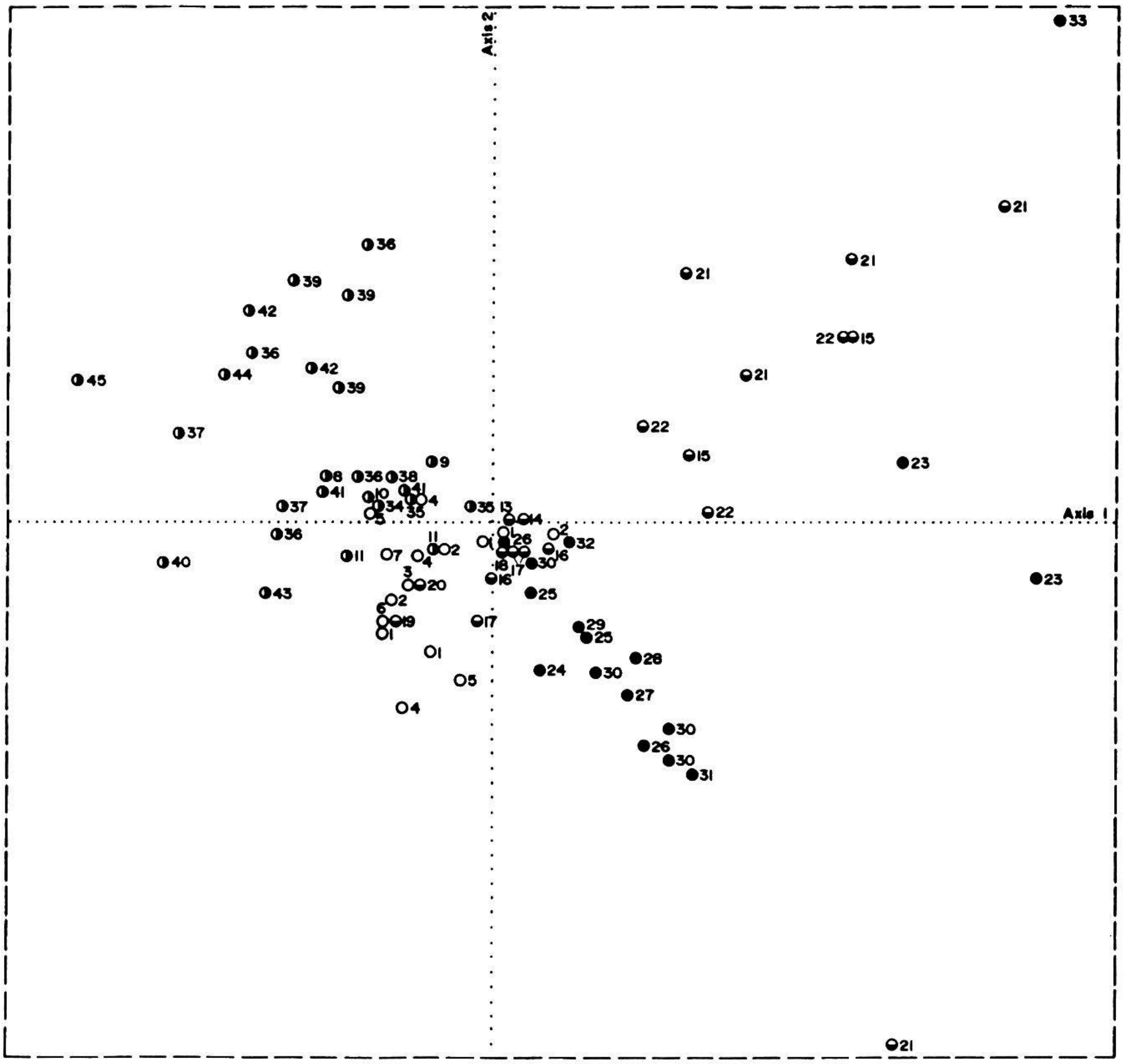

Fig. 4.5. Ordination of slide sections, last survey (Oct. 1985): Separation of four groups

Abb. 4.5. Ordination der Rutsch-Sektionen, letzte Aufnahme (Okt. 1985): Einteilung in vier Gruppen

○ 4 = slide group 1 with transect No.
◑ 36 = slide group 2 with transect No.
⊖ 22 = slide group 3 with transect No.
● 31 = slide group 4 with transect No.

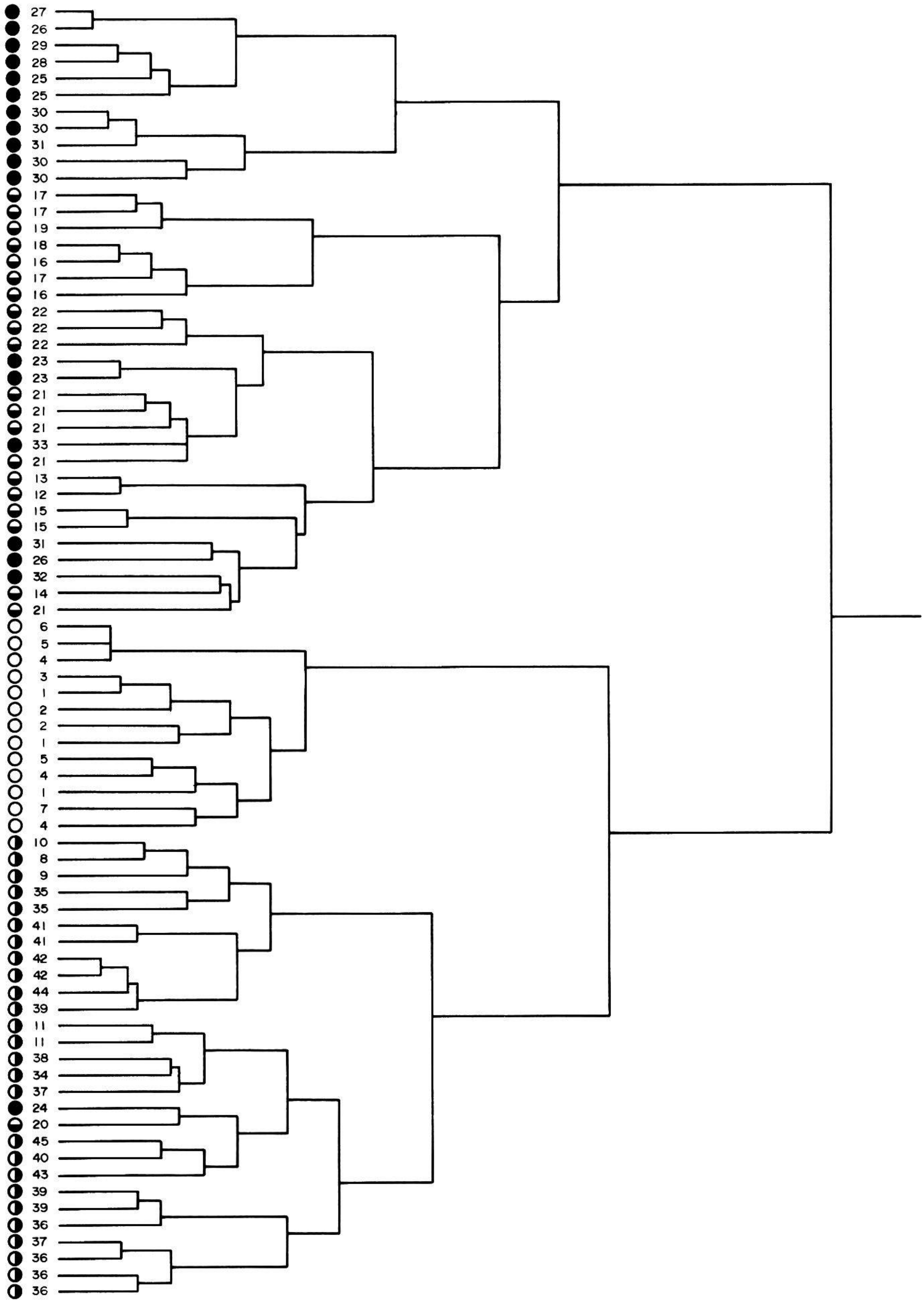
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Fig. 4.7. Study plot 3, transect 7. Anchor in Pinus roxburghii-forest (stable area sl). 27.10.1983

Abb. 4.7. Untersuchungsfläche 3, Transekt 7. Anker in Pinus roxburghii-Wald (intaktes Gebiet sl). 27.10.1983

Fig. 4.6 (p. 36). Cluster analysis of slide sections, last survey (Oct. 1985): Separation of four groups (for legend see Fig. 4.5)

Abb. 4.6 (S. 36). Dendrogramm der Rutsch-Sektionen, letzte Aufnahme (Okt. 1985): Einteilung in vier Gruppen (Legende siehe Abb. 4.5)

Fig. 4.8. Stable area s2. Xerophilous Pinus roxburghii-forest. 27.9.1984

Abb. 4.8. Intaktes Gebiet s2. Xerophiler Pinus roxburghii-Wald. 27.9.1984

Plant composition and frequency of the species for the last survey of group 1 are shown in Table 4.1 (in the pocket of the cover). As a sample for this group, Fig. 4.10 displays a rough map of study plot No. 1 with its transects and sections.

Group 2. Lower middle altitude with a generally southern aspect.

Plots 4-7 and 25-35 (transects 8-11 and 34-45) lie in the upper subtropical belt (DOBREMEZ 1974a,b) between 1600 and 2100 m. The change from the lower subtropical belt is gradual. This area is considerably overexploited.

Plot No. 4 (transect No. 8), protected by a fence by LJRP for stabilization, and plot No. 5 (transect No. 9) are situated in cultivated but poor land, the neighbouring terraces lying fallow during the time of the study. On steep or rocky slopes also found in this area only shrubby vegetation survives (for composition of this vegetation see stable area No. s3).

Plot No. 6 (transect No. 10) (Figs. 4.11, 4.12) lies in what little remains of a mesohygrophilous Schima wallichii forest with a few Lyonia ovalifolia and a well developed shrub layer (see stable area No. s8, Fig. 4.13).

Plot No. 7 (transect No. 11) is a landslide in an afforested area (IHDP afforestation of the whole hill-range since 1975) with Pinus patula (seeds from Kenya) and a very good regeneration of Schima wallichii, Engelhardtia spicata, Eurya acuminata, Myrica esculenta, etc.

Plots 25-33 (transects 34-43) (Figs. 4.14-4.17) are situated in a very cultivated area with practically no forest. In gullies or on slopes Alnus nepalensis is abundant besides the usual shrubby vegetation with mainly Pyrus pashia, Berberis aristata, Osbeckia nepalensis, Phyllanthus parvifolius, Hypericum cordifolium, Eupatorium adenophorum, etc. (see also stable areas s6, s7 and s9-s11).

Fig. 4.9 (p. 38). Stable area s2: Detail of herb layer. 27.9.1984
Abb. 4.9 (S. 38). Intaktes Gebiet s2: Ausschnitt aus der Krautschicht. 27.9.1984

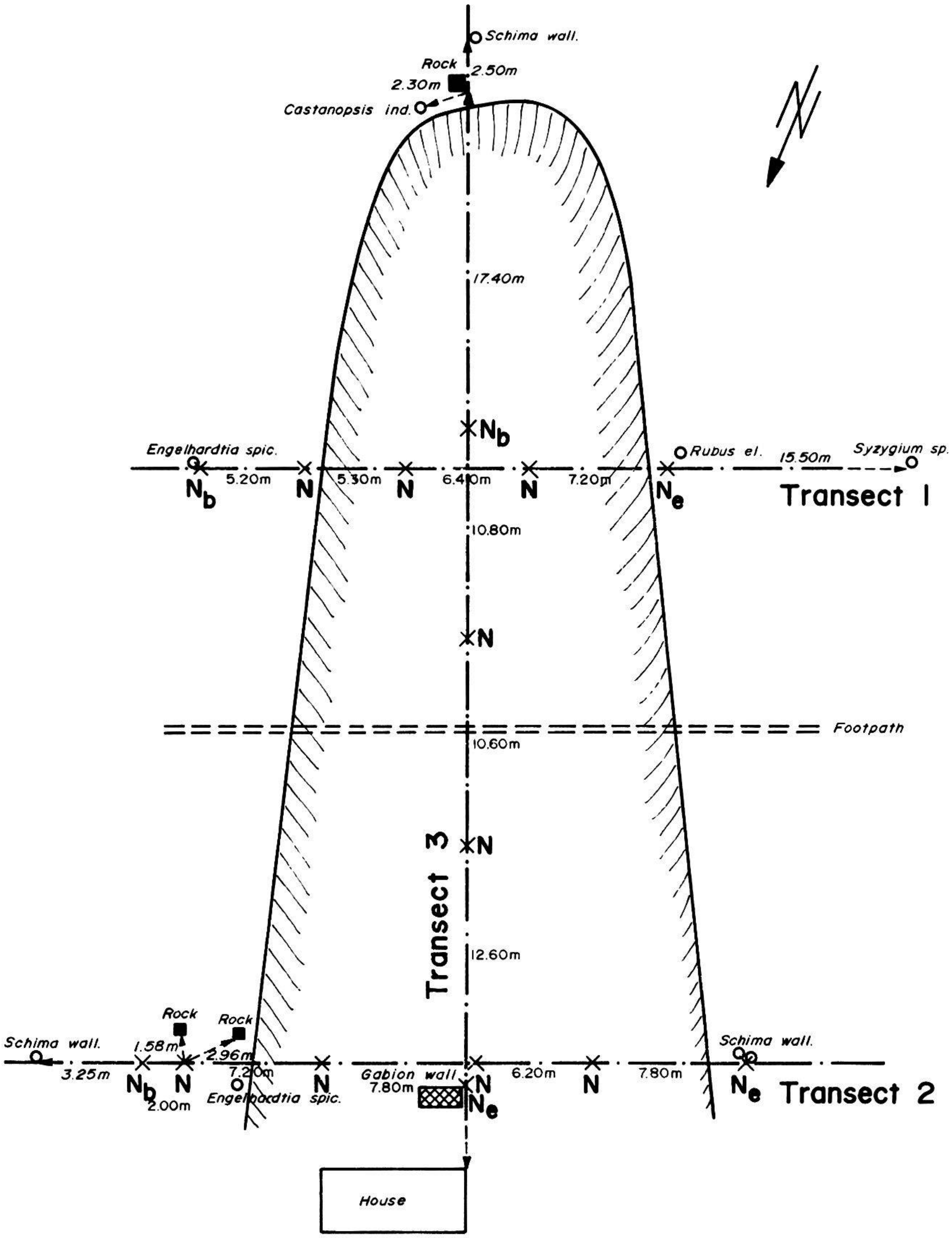


Fig. 4.10. Study plot 1 (not to scale)
Abb. 4.10. Untersuchungsfläche 1 (nicht massstäblich)

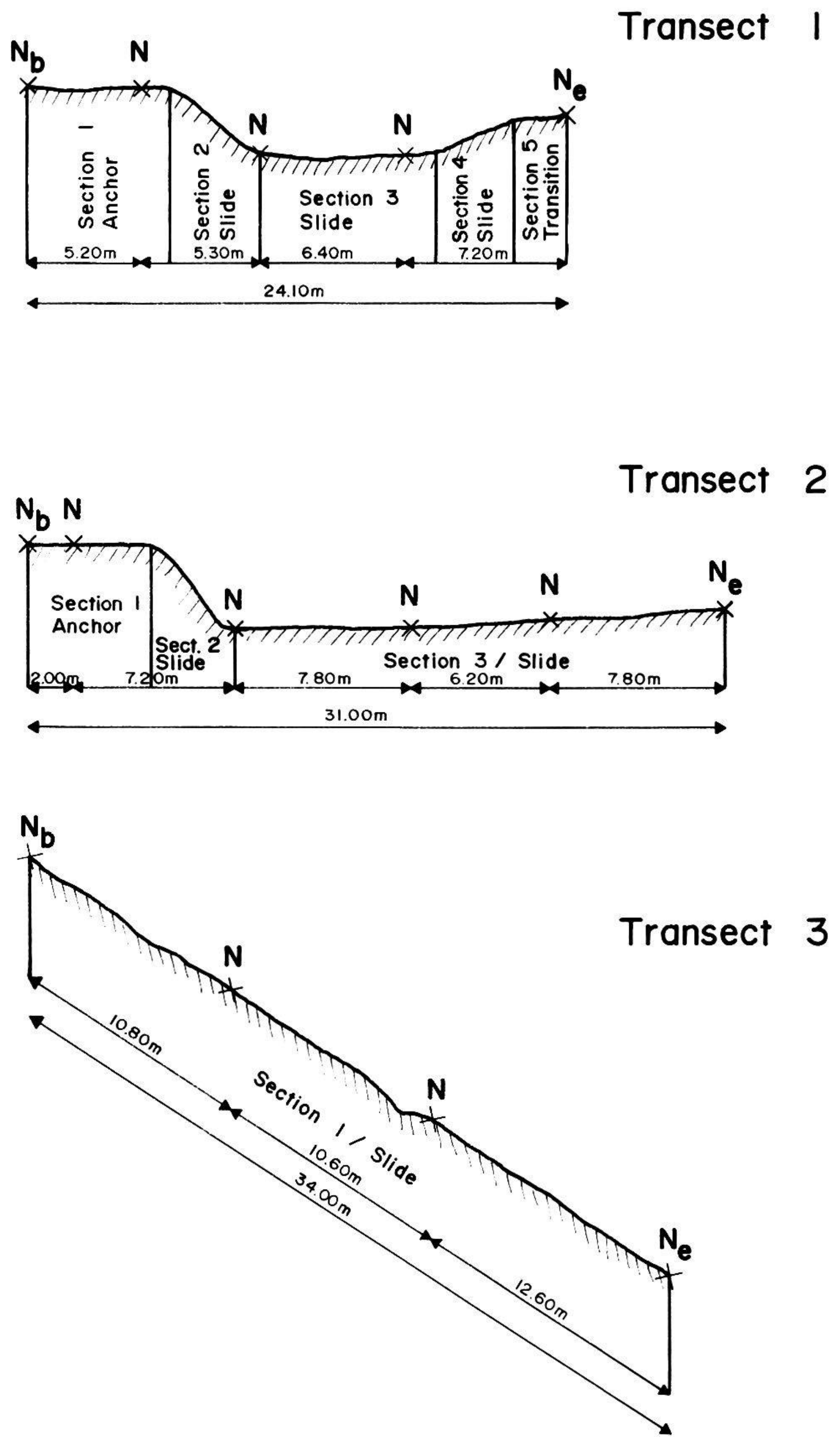


Fig. 4.10 (continued)

N = fixed iron nail
N_b = fixed iron nail, beginning of transect
N_e = fixed iron nail, end of transect

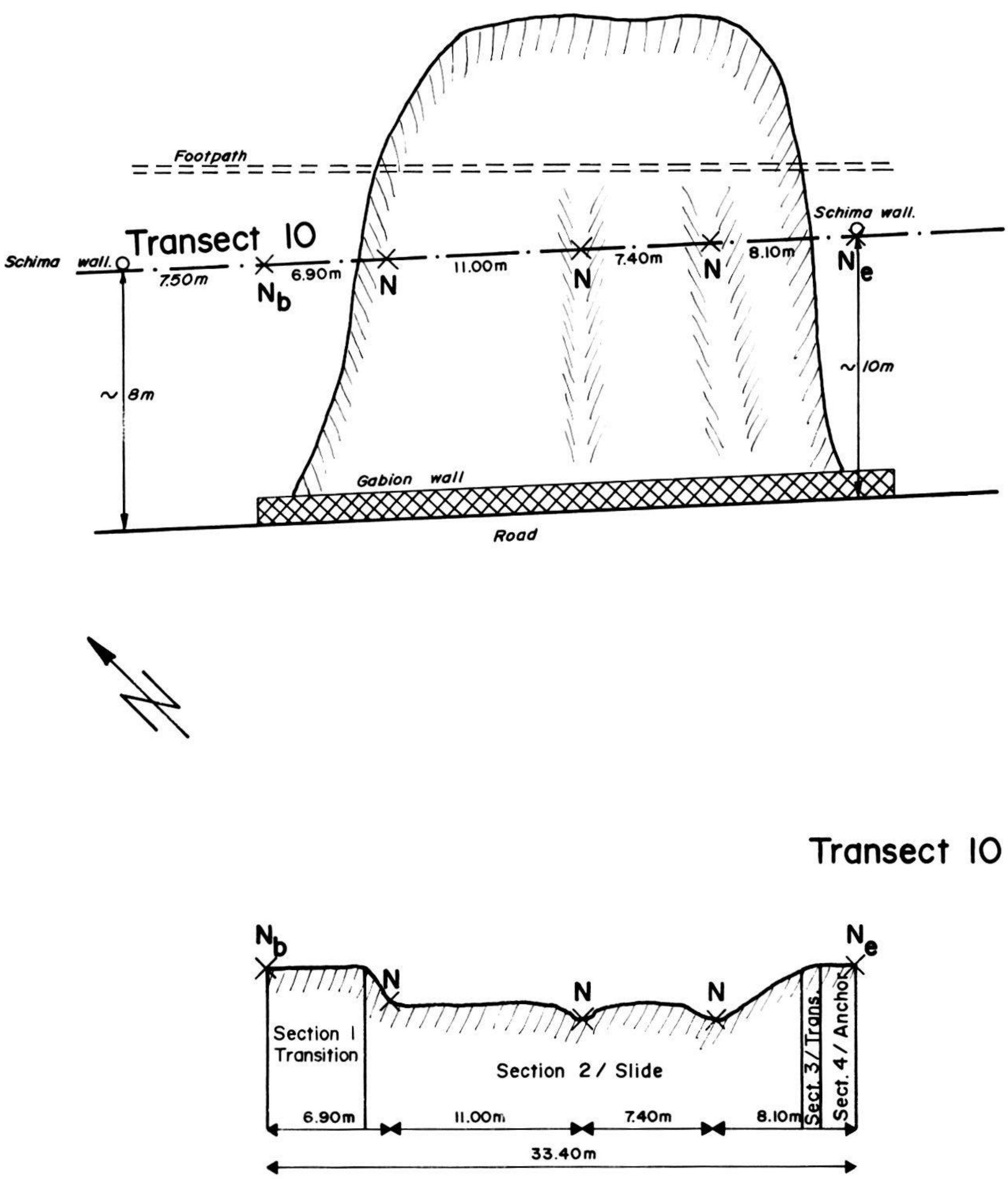


Fig. 4.11. Study plot 6 (not to scale) (for legend see Fig. 4.10)
Abb. 4.11. Untersuchungsfläche 6 (nicht massstäblich) (Legende siehe Abb. 4.10)

Fig. 4.12. Study plot 6, transect 10. Anchor in Schima wallichii-forest (stable area s8). 26.10.1983

Abb. 4.12. Untersuchungsfläche 6, Transekt 10. Anker in Schima wallichii-Wald (intaktes Gebiet s8). 26.10.1983

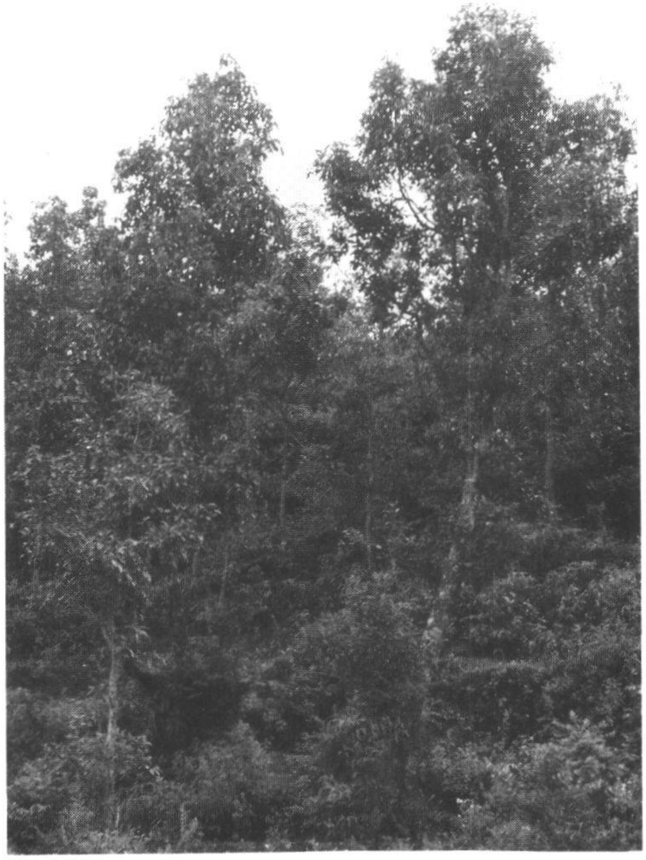


Fig. 4.13. Stable area s8. Mesohygrophilous forest with Schima wallichii. 16.10.1985

Abb. 4.13. Intaktes Gebiet s8. Mesohygrophiler Wald mit Schima wallichii. 16.10.1985

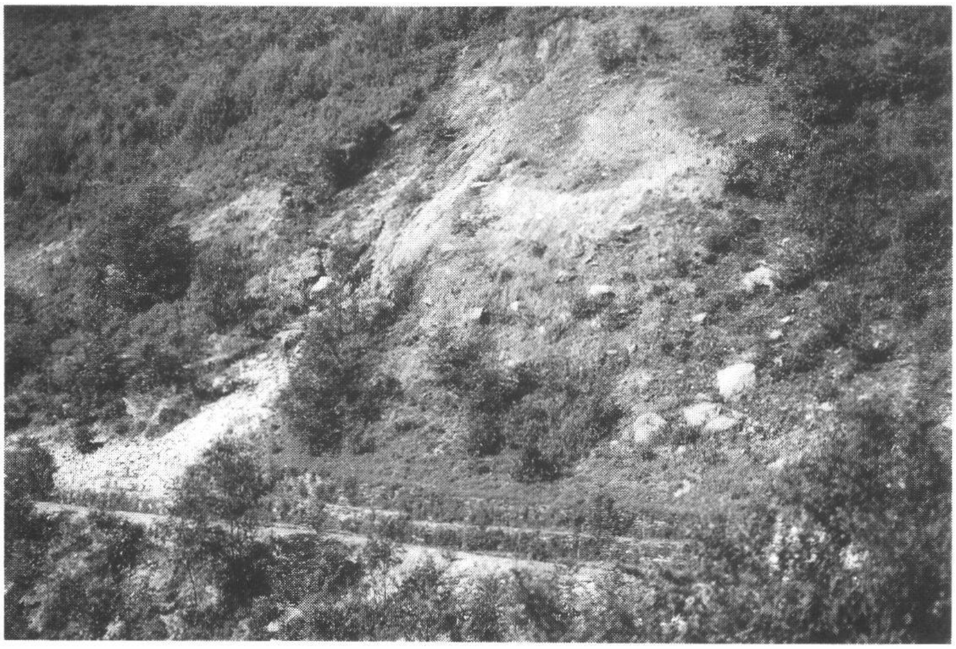


Fig. 4.14. Study plot 26, transect 35. Anchor in shrubland. 8.10.1984
Abb. 4.14. Untersuchungsfläche 26, Transekt 35. Anker in Buschland. 8.10.1984

Fig. 4.15. Study plot 27, transect 37. Planted with Alnus nepalensis; Saccharum spontaneum in flower. 17.10.1983
Abb. 4.15. Untersuchungsfläche 27, Transekt 37. Bepflanzt mit Alnus nepalensis; Saccharum spontaneum im Vordergrund blühend. 17.10.1983

Plots 34 and 35 (transects 44 and 45) (Fig. 4.18) lie in a mesohygrophilous forest with Schima wallichii, Castanopsis indica, Engelhardtia spicata, Lyonia ovalifolia, Rhododendron arboreum, etc. (see stable areas s4 and s5, Figs. 4.19, 4.20). This forest still exists, although considerably exploited.

Plant composition and frequencies of the last survey of group 2 are shown in Table 4.2 (in the pocket of the cover) and as a sample study plot No. 6 with its transects and sections is sketched in Figure 4.11.

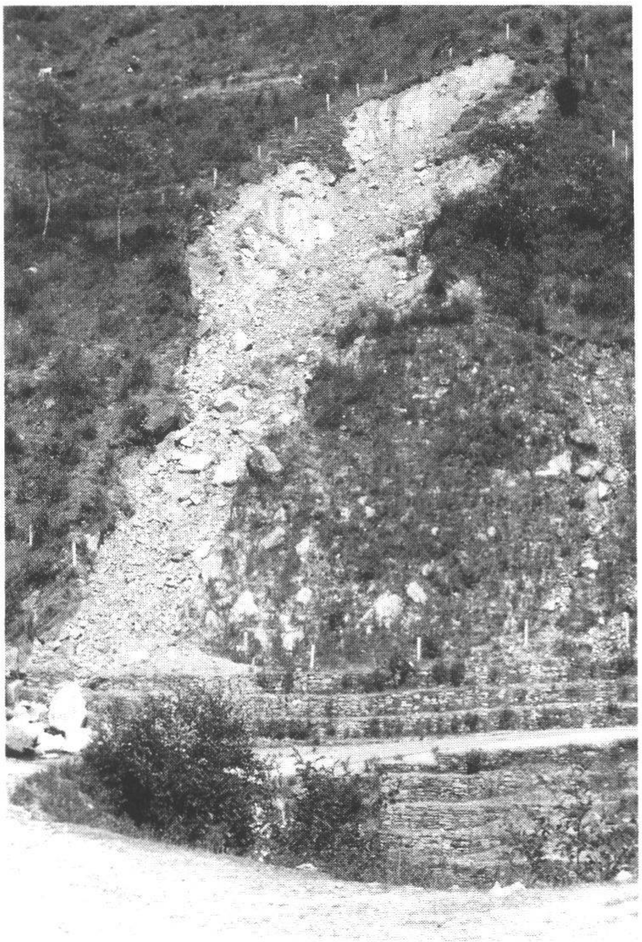


Fig. 4.16. Study plot 28, transect 38. Anchor in shrubland with Alnus nepalensis. 17.10.1983

Abb. 4.16. Untersuchungsfläche 28, Transekt 38. Anker in Buschland mit Alnus nepalensis. 17.10.1983

Group 3. Higher middle altitude with a generally northern aspect.

Plots 8-15 (transects 12-22) (Figs. 4.21-4.24) lie between 1900 and 2200 m, i.e. in the upper subtropical belt, advancing into the middle hill belt (DOBREMEZ 1974a,b). The northern aspect enables some forests to survive.

The anchor vegetation of plots 8-13 (transects 12-20) varies between shrubland and hygrophilous forest with Alnus nepalensis, Eurya acuminata, Myrsine semiserrata, Berberis aristata, B. asiatica, Rubus ellipticus, etc.

Plots 11 and 12 (transects 16-19) face south or southwest and could be defined as a subgroup as they have a high pH-value. They are the only plots were $CaCO_3$ was found in the soil. The presence of Polygala triphylla and to some extent Eulalia mollis seems to be related to this.

Plots 14 and 15 (transects 21 and 22) are situated in an area covered with a reasonably intact hygrophilous forest with Daphniphyllum himalayensis dominating, accompanied by Alnus nepalensis, Lyonia ovalifolia, Eurya and Symplocos species etc. (see stable areas s12a-s12d, Fig. 4.25). A large part of this forest has been protected by an IHDP-fence since 1981, no grazing or cutting of firewood having been allowed.

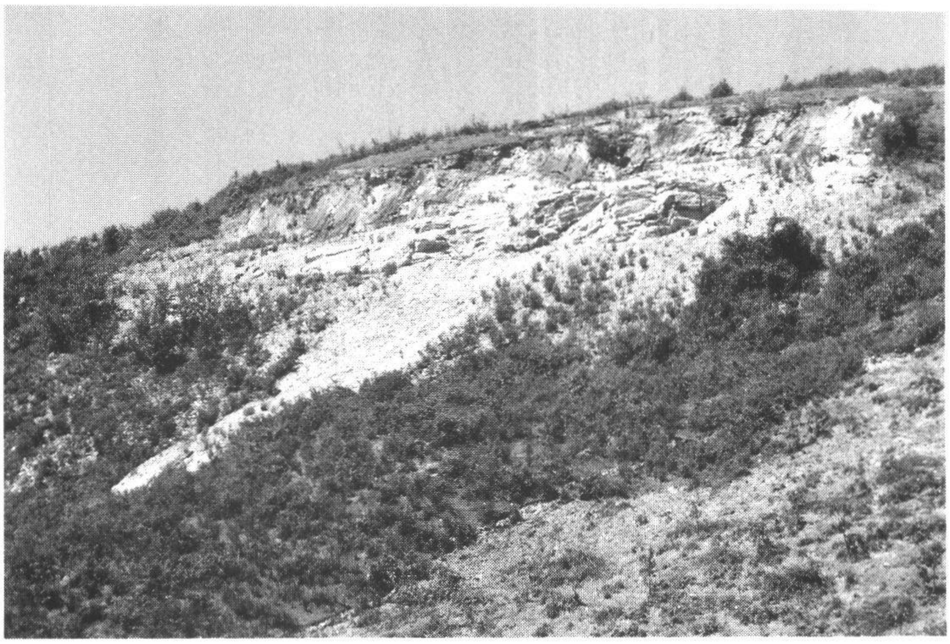


Fig. 4.17. Study plot 32, transect 42. Anchor in Eupatorium-shrubland (stable area s7). 2.10.1984

Abb. 4.17. Untersuchungsfläche 32, Transekt 42. Anker in Eupatorium-Buschland (intaktes Gebiet s7). 2.10.1984

The floral composition and plant frequencies of the last survey of group 3 are given in Table 4.3 (in the pocket of the cover). Figure 4.26 shows a sketch of study plot No. 15 as a sample for this group.

Group 4. High altitude.

Plots 16-24 (transects 23-33) are situated in the middle hill belt between 2300 and 2600 m (DOBREMEZ 1974a,b). The pastures and forests are much exploited, the trees, especially Quercus semecarpifolia, being heavily lopped.

The plots 16-21 (transects 23-29) (Figs. 4.27, 4.28) lie in pasture land with Hemiphragma heterophyllum, Potentilla fulgens, Arundinella hookeri, Agrostis pilosula, Arthraxon lancifolius und Carex sp. as main representatives of the herb layer.

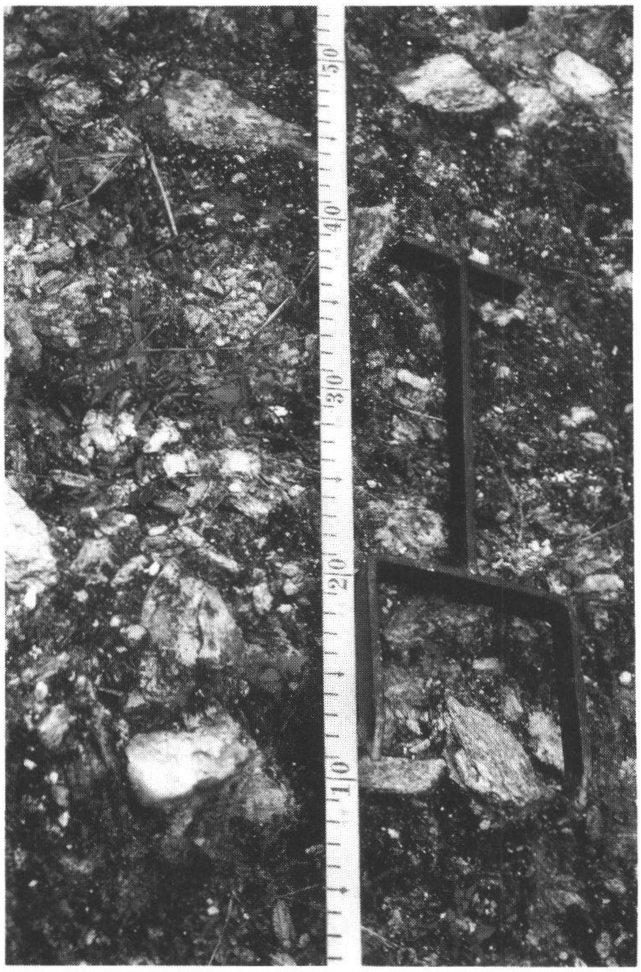


Fig. 4.18. Study plot 35, transect 45: Detail of slide section. 17.6.1984

Abb. 4.18. Untersuchungsfläche 35, Transekt 45: Ausschnitt aus der Rutsch-Sektion. 17.6.1984

The anchor of plots 22-24 (transects 30-33) (Figs. 4.29-4.31) consist of mesohygrophilous forest with Quercus semecarpifolia, Pieris formosa, Rhododendron arboreum and Symplocos species (see also stable area No. s13).

The floral composition and plant frequencies of the last survey of group 4 are shown in Table 4.4 (in the pocket of the cover); Figure 4.32 outlines study plot No. 19 as representative for this group.

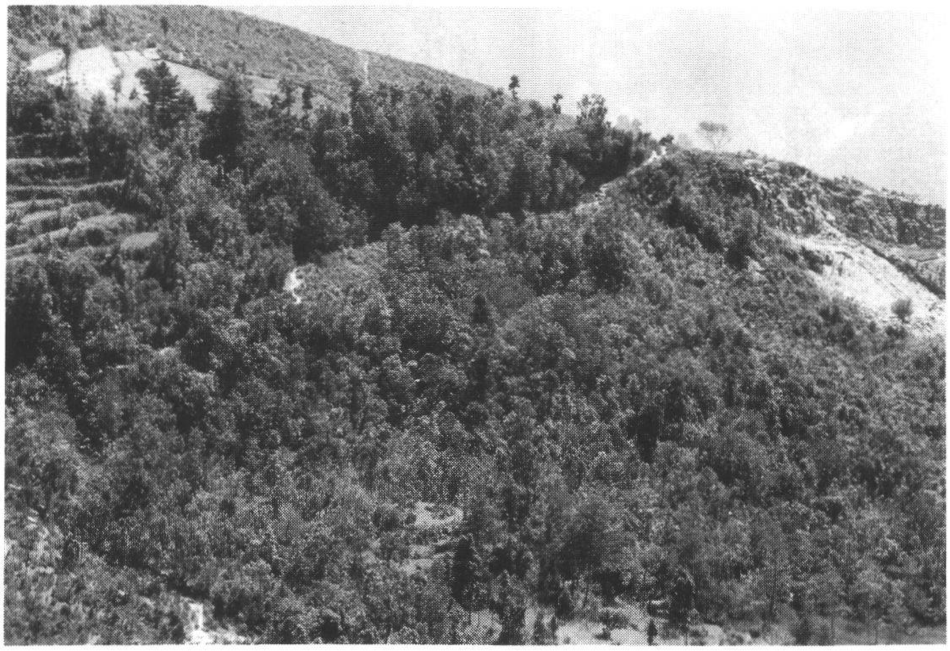


Fig. 4.19. View of stable area s4. Mesohygrophilous forest with Schima wallichii, Castanopsis indica, Rhododendron arboreum. 2.10.1984

Abb. 4.19. Blick auf das stabile Gebiet s4. Mesohygrophiler Wald mit Schima wallichii, Castanopsis indica, Rhododendron arboreum. 2.10.1984

Fig. 4.20 (p. 49). Stable area s4: Detail of mesohygrophilous forest. 27.9.1984

Abb. 4.20 (S. 49). Stabiles Gebiet s4: Ausschnitt aus dem mesohygrophilen Wald. 27.9.1984

Fig. 4.21 (p. 49). Study plot 9, transect 14. Alnus nepalensis growing in foreground. 14.10.1984

Abb. 4.21 (S. 49). Untersuchungsfläche 9, Transekt 14. Im Vordergrund mit Alnus nepalensis. 14.10.1984

Fig. 20 (see legend p. 48)

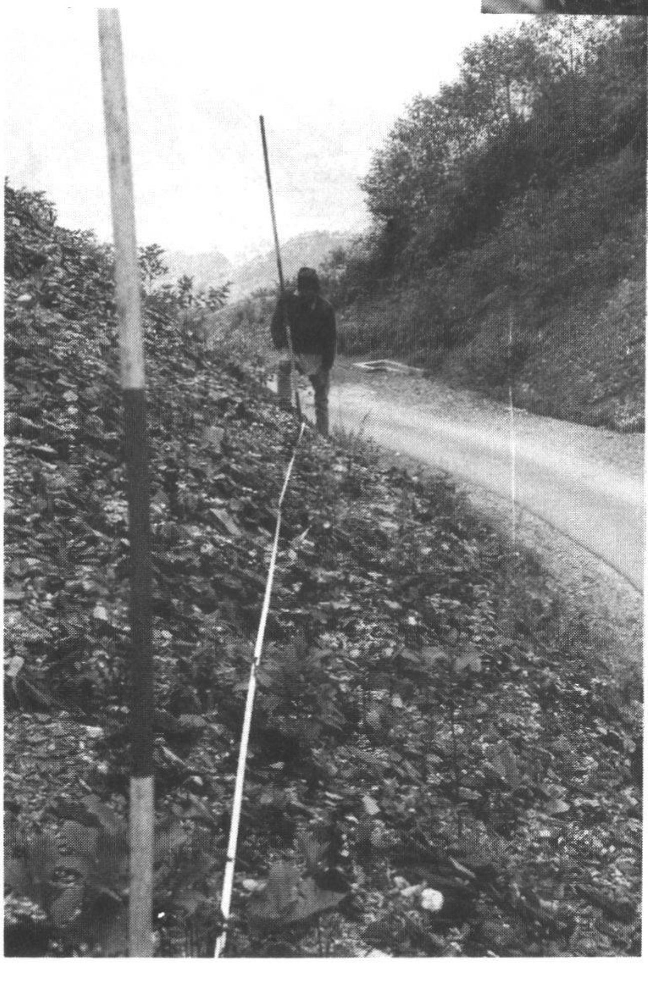


Fig. 21 (see legend p. 48)

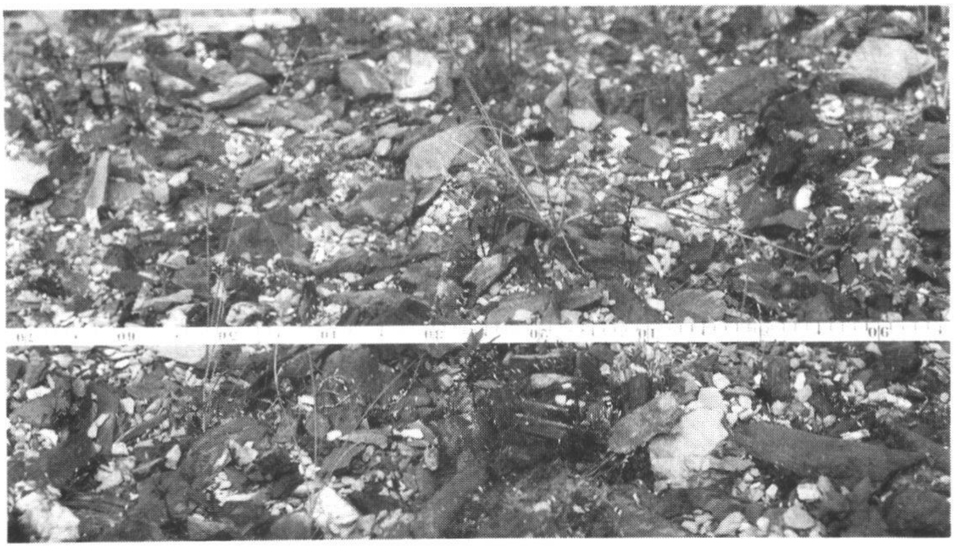


Fig. 4.22. Study plot 9, transect 14: Detail of slide section on lithosol. 14.10.1984
Abb. 4.22. Untersuchungsfläche 9, Transekt 14: Ausschnitt aus der Rutsch-Sektion auf Lithosol. 14.10.1984

Fig. 4.23. Study plot 11, transect 18 (vertical). 24.10.1983
Abb. 4.23. Untersuchungsfläche 11, Transekt 18 (vertikal). 24.10.1983

Fig. 4.24. Study plot 14, transect 21. Anchor in hygrophilous Daphniphyllum himalayense-forest (stable area sl2). 12.10.1984
Abb. 4.24. Untersuchungsfläche 14, Transekt 21. Anker in hygrophilem Daphniphyllum himalayense-Wald (intaktes Gebiet sl2). 12.10.1984

4.1.2. Stable areas

The monsoon climate promotes the development of a rich flora (DOBREMEZ 1976, KANAI et al. 1975, POLUNIN and STAINTON 1984). The records of some relatively stable areas, ranging from grassland or pasture to shrubland and forest, illustrate this well.
A list of the 13 stable areas recorded, their site factors and their characteristic plant society is given in Table 3.2. These stable areas are also related to groups 1-4 of the landslides and slopes according to the vegetation zonation scheme of DOBREMEZ (1974b). In Table 4.5 (in the pocket of the cover) the abundance of the species in the stable areas is noted.

The plots s9 and s11 (Fig. 3.4) lie in grassland. No. s9 is grazed on regularly; Imperata cylindrica and to some extent Schizachyrium brevifolium dominate. On No. s11, which has not been grazed but only cut since 1980, there is much Imperata and Schizachyrium, and Arundinella nepalensis, Sacciolepis indica and Sporobolus piliferus are also abundant. The plot is on the whole much richer in species.

The areas s3, s6, s7 and s10 (Figs. 3.2, 3.3, 4.17) represent shrubland with Eupatorium adenophorum dominating besides Phyllanthus parvifolius and Osbeckia stellata. Some Pyrus pashia may develop, or even Schima wallichii as on No. s3. This plot was in poor condition in March 1984; but after being fenced as a testplot for erosion control in April 1984, it developed quickly, which can be noted by comparing the fenced plot

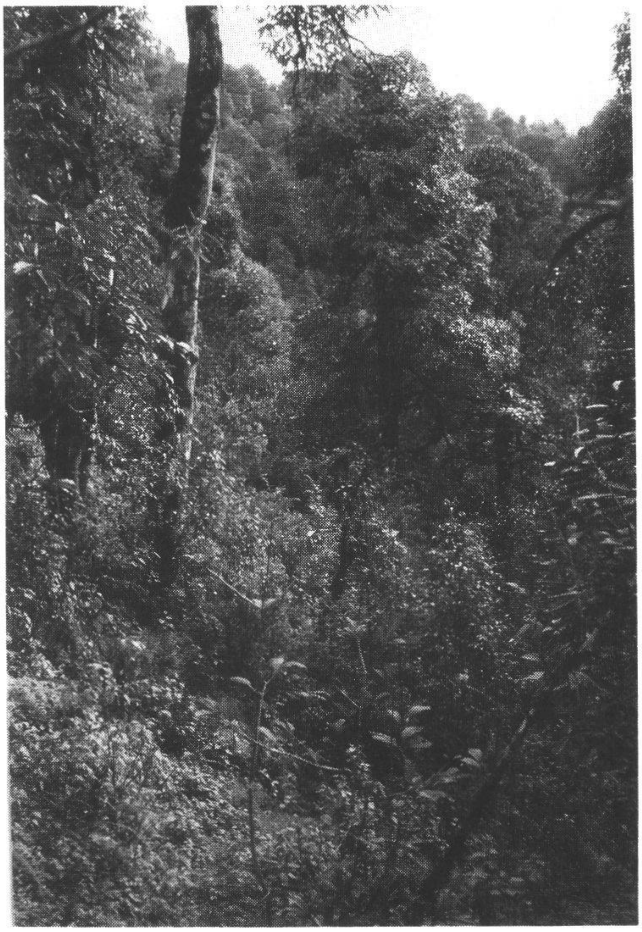


Fig. 4.25. Stable area s12. Hygrophilous forest with Daphniphyllum himalayense. 12.10.1984

Abb. 4.25. Intaktes Gebiet s12. Hygrophiler Wald mit Daphniphyllum himalayense. 12.10.1984

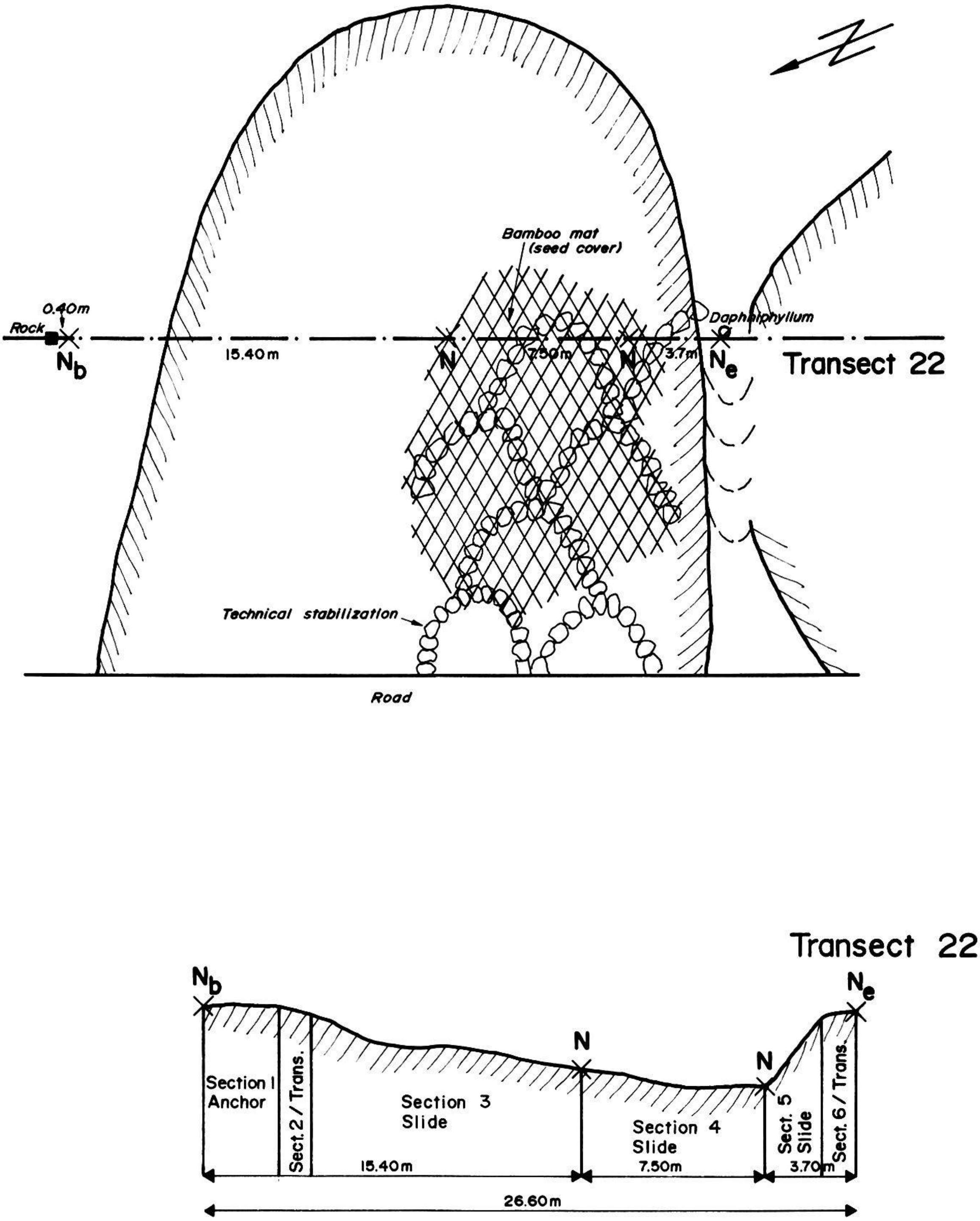


Fig. 4.26. Study plot 15 (not to scale) (for legend see Fig. 4.10)
Abb. 4.26. Untersuchungsfläche 15 (nicht massstäblich) (Legende siehe Abb. 4.10)

Fig. 4.27. Study plot 18, transect 25. Anchor in pasture land. 17.10.1983

Abb. 4.27. Untersuchungsfläche 18, Transekt 25. Anker in Weideland. 17.10.1983

Fig. 4.28. Study plot 21, transect 29. Anchor in pasture land. 17.10.1983

Abb. 4.28. Untersuchungsfläche 21, Transekt 29. Anker in Weideland. 17.10.1983 with the surrounding area on Figures 3.2 and 3.3. The shrubland areas, though grazed on regularly by cattle and goats, are usually well covered by plants. But an interpretation of the vegetation table alone can be deceptive. The herb layer - even if rich in species - is, with the exception of Eupatorium and a few other unpalatable plants, very short; particularly the nutritious Gramineae and herbs like Arundinella, Arthraxon, Sacciolepis, Sporobolus, Taraxacum, Smithia etc. are diminutive.

Fig. 4.29. View of study plot 22, transect 30, 31. Anchor in mesohygrophilous forest with Quercus semecarpifolia (stable area sl3). June 1985

Abb. 4.29. Blick auf Untersuchungsfläche 22, Transekt 30, 31. Anker in mesohygrophilem Wald mit Quercus semecarpifolia (intaktes Gebiet sl3). Juni 1985

The stable areas s1 and s2 (Figs. 4.7-4.9) represent xerophilous Pinus roxburghii-forests. No. s1 had been protected from burning and grazing for eight years till 1980; after burning in 1980, protection started again in 1982, which is to last till 1989. The shrub and especially the herb layer of No. s1 are much richer in species than the layers of No. s2, where burning and grazing is a regular occurrence.
The areas s4, s5 and s8 (Figs. 4.13, 4.19, 4.20) lie in mesohygrophilous forest. In No. s8, the very small remains of a forest, Schima wallichii is the dominant tree species, besides which only a few Lyonia ovalifolia occur. The shrub layer is dominated by Dicranopteris linearis and Phyllanthus parvifolius. The areas s4 and s5 are samples of a mixed forest with Schima wallichii, Rhododendron arboreum and Castanopsis. No. s4 in particular, which, unlike No. s5, lies in the center of the quite well preserved small forest, is rich in species in all the layers.
Nos. s12a-s12d (Fig. 4.25) are records from different plots of the same hygrophilous forest with Daphniphyllum himalayense dominating. Symplocos crataegoides and Alnus nepalensis are abundant too. Besides the well developed shrub layer with Viburnum erubescens, Daphne bholua, Sarcococca

Fig. 4.30. Study plot 22, transect 30. Anchor in heavily lopped Quercus semecarpifolia-forest. 8.10.1984
Abb. 4.30. Untersuchungsfläche 22, Transekt 30. Anker in stark geschneiteltem Quercus semecarpifolia-Wald. 8.10.1984

pruniformis etc., the herb layer is rich in species, with Strobilanthes sp., Ellisiophyllum pinnatum, Chambainia cuspidata and Athyrium sp. as main species. To protect the forest, IHDP installed a fence around an area of about 25 ha in 1981 (SINGY 1982).

Stable area sl3 (Figs. 4.29-4.31) is part of a mesohygrophilous forest with Quercus semecarpifolia as dominant tree. The area is much exploited: The oaks are heavily lopped and the whole slope is grazed on regularly. The shrub layer is undeveloped and the herb layer is rather poor in species with Strobilanthes sp., Anaphalis triplinervis, Anaphalis contorta and Arthraxon lancifolius dominating.

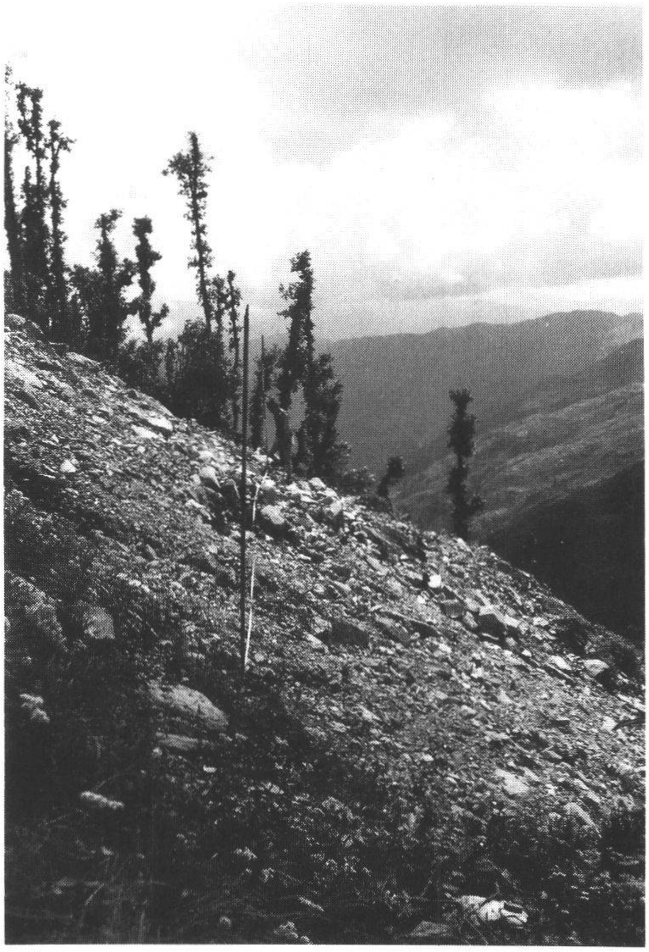
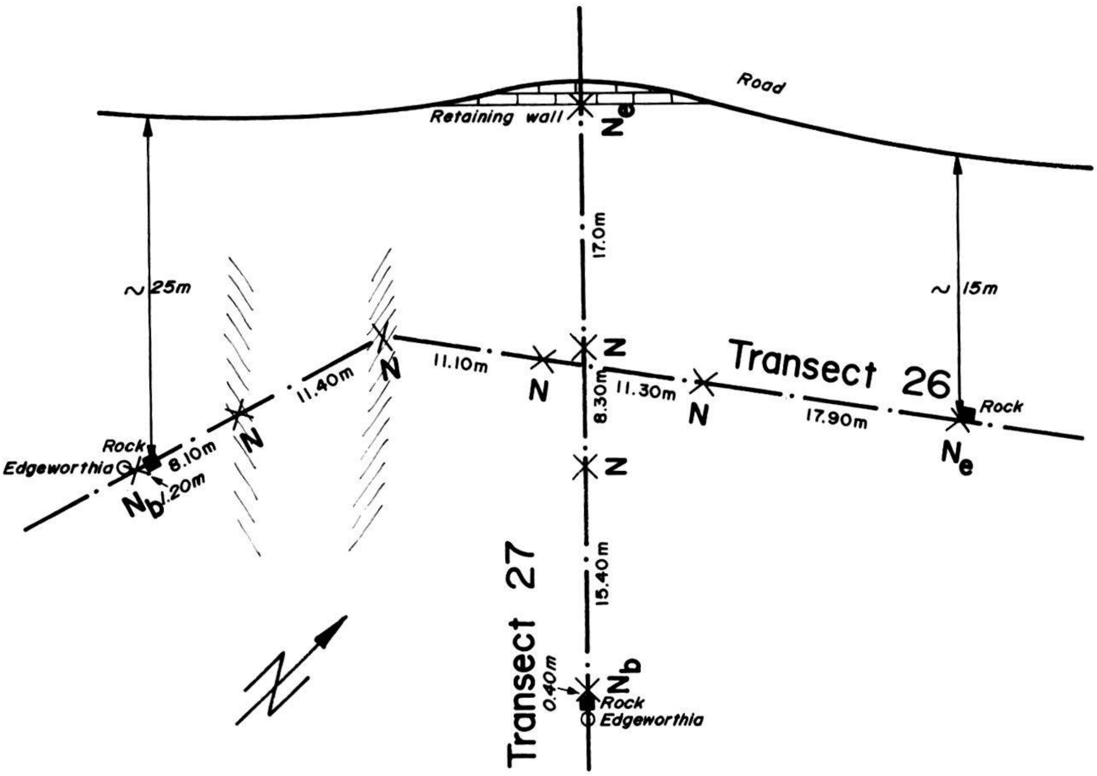
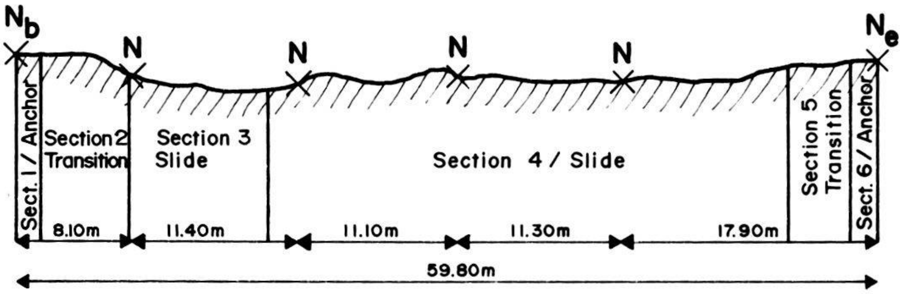


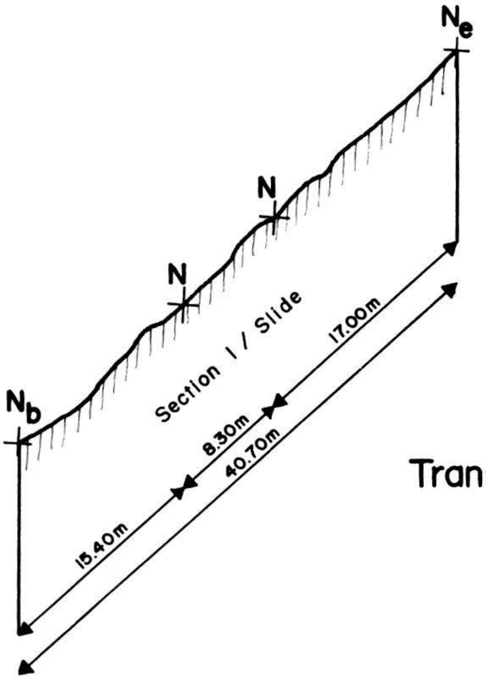
Fig. 4.31. Study plot 22, transect 30. Anchor in heavily lopped Quercus semecarpifolia-forest. 8.10.1984

Abb. 4.31. Untersuchungsfläche 22, Transekt 30. Anker in stark geschneiteltem Quercus semecarpifolia-Wald. 8.10.1984



Transect 26





Transect 27

4.1.3. Plant communities of unstable slopes

Group 1. Low altitude.

The dominance of Eupatorium adenophorum, Pogonatherum sp., Gonostegia hirta, Phyllanthus parvifolius, Brachiaria villosa and Pogonatum seminudum is conspicous. Besides this the following communities can be found (Table 4.1., in the pocket of the cover):

- General slide community on rather unstable slopes, with northern aspect: This community is dominated by mosses, especially Pogonatum junghuhnianum, and Vandellia sp.; Desmodium concinuum is fairly abundant too. Alnus nepalensis, though cultivated (study plot 1, transects 1-3), shows good growth.
- General slide community on rather stable slopes, with northern and southern aspect: Here Schizachyrium brevifolium, Osbeckia nepalensis, Murdannia nudiflorum, Fimbristylis dichotoma are abundant besides a variety of other species.
- Older slide community, northern aspect, rather wet. In addition to the previous community Drymaria diandra, Eriocaulon nepalensis and Cyperus aristatus appear, indicating a wet ground.

Group 2. Lower middle altitude with a generally southern aspect.

Here too, Eupatorium adenophorum and Pogonatherum sp. are dominant, supplemented with Arundinella nepalensis, Sporobolus piliferus, Brachiaria villosa, Sacciolepis indica, Imperata cylindrica, Pogonatum junghuhnianum and P. seminudum. Alnus nepalensis, often cultivated, grows without restraint. Among this basic species group the following communities are found (Table 4.2, in the pocket of the cover):

- General slide community with Arthraxon lancifolius, Vandellia nummularifolia, Drymaria diandra, Hypericum japonicum etc.
- Dispersed slide community with Eragrostis atrovirens and Polygonum nepalensis.
- The community on plot 27 (transects 36, 37, Fig. 4.15), an old, sandy and wet landslide with only 50% slope, shows as variant of the region

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Fig. 4.32 (p. 58). Study plot 19 (not to scale) (for legend see Fig. 4.10)
Abb. 4.32 (S. 58). Untersuchungsfläche 19 (nicht massstäblich) (Legende siehe Abb. 4.10)

Chrysopogon gryllus, Saccharum spontaneum, Calamagrostis pseudophragmites combined with the general slide community.

Group 3. Higher middle altitude with a generally northern aspect.

The older slides are generally covered with Eupatorium adenophorum, Microstegium nudum, Chambainia cuspidata, Hypericum uralum, Alnus nepalensis (only partly cultivated), Pogonatum seminudum. Besides these plants two main groups can be distinguished (Table 4.3, in the pocket of the cover):

- General slide community on younger or dry slopes with poor soil, or pH-value higher than 6.7: Pogonatherum sp., Anaphalis contorta, Eulalia mollis, Polygala triphylla dominate.
- General slide community on older, more developed or wet slopes with richer soil and low pH: Gaultheria fragrantissima, Hydrocotyle sp., Impatiens sp., Microstegium ciliatum, Drymaria diandra, Pogonatum junghuhnianum etc. are abundant.

Group 4. High altitude.

The dominant species in the slide sections at this altitude are Pogonatum sp., Dicranella sp., Anaphalis contorta, Impatiens sp., Hemiphragma heterophyllum, Arthraxon lancifolius, Carex atrata, Arundinella hookeri etc. Within this basic group three specific communities can be seen (Table 4.4, in the pocket of the cover):

- Slide community on poorer soil with Gaultheria fragrantissima, Lyonia ovalifolia, Digitaria ascendens, Rubus ellipticus.
- Slide community on wet, richer soil: It combines the previous community with Hydrocotyle spp., Calaminthe umbrosum, Stellaria patens, Mazus japonicus, Plantago major.
- Slide community on wet soil with Chambainia cuspidata, Gonostegia hirta, Drymaria diandra, Selaginella sp., Cyanotis sp., Swertia sp., etc.

4.1.4. Development and change

Generally it was found that the plant cover on the slide sections became denser during the three years of the study. The increasing plant frequencies in Table 4.6 (in the pocket of the cover) of the three postmonsoon records (1983-1985) of group 1 illustrate this fact. With regard to the floral composition, a certain development of the slide sections towards the transitions, and of the transitions towards the anchors can be observed. Table 4.7 (in the pocket of the cover) gives an overview of the most represented species in the three sections of the four groups of the study. It is not possible to draw a strict line between the groups and the sections since environmental factors such as altitude, aspect, soil, etc. interfere too much.

The first plants to appear on a young slide are usually mosses, especially Pogonatherum sp. At lower altitudes they are followed by Gramineae like Pogonatherum sp. and Schizachyrium brevifolium, at middle altitudes Sporobolus piliferus and Brachiaria villosa predominate and at higher altitudes Arthraxon lancifolius is abundant. Alnus nepalensis and Eupatorium are usually among the first settlers; in the studied plots this fact was often supported by planting or sowing Alnus, and in some places Eupatorium. At low altitudes Gonostegia hirta and often Osbeckia nepalensis appear soon too, at middle altitudes Drymaria diandra, Chambainia cuspidata and Polygonum uncinatum and at high altitudes Anaphalis contorta.

If undisturbed, the plant cover on a slide gets denser and richer in species quite quickly, especially in the favourable climates of lower and middle altitudes. More ambitious Gramineae appear like Hackeochloa granularis at low altitude (but Pogonatherum is still dominant), Imperata cylindrica and Calamagrostis pseudophragmites on dry slopes at middle altitude and Microstegium nudum, Eulalia mollis and Pogonatherum sp. on wetter slopes. The number of shrubs and perennials is increasing with Phyllanthus parvifolius, Hypericum cordifolium and abundant Osbeckia nepalensis at low altitude, Berberis aristata and B. asiatica, Eupatorium adenophorum, Anaphalis contorta and Gonostegia hirta at southfacing middle altitude, Gaultheria fragrantissima, Phyllanthus parvifolius, Artemisia sp., Ellisiophyllum pinnatum and Selaginella sp. at more northfacing middle altitude. At high altitude, besides the increasing number of species also typical for relatively undisturbed grassland like Agrostis pilosula, Arundinella hookeri, Eragrostis papposa, Tripogon filiformis, Carex atrata, Bulbostylis capillaris and Potentilla fulgens, also Rubus nepalensis, Elsholtzia pilosa and Hemiphragma heterophyllum appear. With the exception of Alnus and - only on dryer slopes of the low altitude - Pinus roxburghii, the trees settle hesitantly. Schima wallichii and more seldom Lyonia ovalifolia can be found at lower and middle altitudes, Rhododendron arboreum - slow growing - at middle and high altitudes.

The appearance of trees and other perennials leads from the transition to the anchor sections. Obviously, quite a number of species are found in either of them, but the anchors are much richer in species. Some plants seem to prefer a stabilized situation and occur almost only in anchors or in sections which have somewhat consolidated. In lower altitudes this is true for Engelhardtia spicata, Castanopsis indica, Indigofera dosna, Dicranopteris linearis and to some extent Imperata cylindrica, Cheilanthes farinosa and Pteridium aquilinum. In middle altitudes with southern aspect Eurya spp., Lyonia ovalifolia, Gaultheria fragrantissima, Arundinella nepalensis, Carex cruciata and Dicranopteris linearis and in middle altitudes with northern aspect Eurya spp., Myrsine semiserrata, Neillia thyrsiflora, Carex spp., Ellisiophyllum pinnatum, Lycopodium clavatum, Ptychanthus sp. and to some extent Dicranopteris linearis, Pteridium aquilinum, Selaginella sp. and Ectropothecinus sp. all seem to prefer a more stable plot. At high altitude species like Quercus semecarpifolia, Symplocos spp., Microstegium spp., Oryzopsis lateralis, Carex cruciata, Roscoea purpurea, Anemone rivularis, Strobilanthes sp. and Valeriana hardwickii are seldom found on unstable sites.

The seasonal changes of the plant cover in the slide and transition sections is conspicuous. While young shoots on trees like Alnus nepalensis, Daphniphyllum himalayense, Lyonia ovalifolia and Rhododendron arboreum and on perennials like Anaphalis contorta and Eupatorium adenophorum sprout strongly already in March and April, the ground of the studied slides stayed bare and dry - if not covered by Alnus or Eupatorium - except perhaps for a few perennial Gramineae like Imperata cylindrica, Eragrostis papposa, Poa sp., or some Carex or Polygonum spp. Tables 4.8 and 4.9 (in the pocket of the cover) represent the plant cover from a selection of the best covered plots in April 1985. With the start of the premonsoon rains in April/May and at the beginning of the monsoon in mid-June, the seedlings start growing abundantly and the more stable or older slides are soon quite well covered. Table 4.10 (in the pocket of the cover) with the plants recorded in June/July 1985 on the plots of group 1 illustrate this. In the early monsoon time it is difficult to identify the numerous young Gramineae, but by August, September and October most of the Gramineae are flowering, the herbs and shrubs are in full sap. With the decreasing precipitation after the monsoon in October

and November the plants get drier or disappear again.
The following is an attempt to interpret the changes of the vegetation cover over the three years of the study, mainly relying on the three September/October surveys from 1983-1985. As mentioned earlier, for each of the groups an ordination (scatter diagram) as well as a cluster analysis (dendrogram) was computed and a plant frequency table was printed. To give an impression of the interplay of these different possibilities of investigating a development trend, Table 4.6 (plant frequency; in the pocket of the cover), Fig. 4.33 (ordination) and Fig. 4.34 (cluster analysis) of group 1 are displayed. The evaluation has been done in the same way for group 2-4. But here, for the sake of lucidity, only the ordination graphs are shown. The additional data have been deposited in the archivs of the Geobotanical Institute.

Group 1. Low altitude.

Fig. 4.33 shows the scatter diagram of the relevés and species of the three postmonsoon records of group 1. The additional study of the cluster analysis (Fig. 4.34) and the frequency table (Table 4.6, in the pocket of the cover) tend to confirm the following interpretations:
The five anchor sections of plots No. 1 (transects 1-3) and No. 2 (transects 4-6) lie close to the second axis. The related species are Engelhardtia spicata, Lyonia ovalifolia, Phyllanthus parvifolius, Oplismenus compositus and Dicranopteris linearis.
Slide No. 1 occurred during monsoon 1981. Most of its slide sections lie in the fourth quadrant, connected with Alnus nepalensis, which was planted in this slide by LJRP for stabilization. These sections show, if not a straight line, a clear movement towards the anchors. Slide No. 2 dates back to monsoon 1977. Its slide sections lie and point generally more towards the anchors than those of No. 1. Frequency table 4.6 shows clearly that they have a denser plant cover, richer in species, than No. 1. This may indicate a more advanced development.
The transition section of transect No. 2 points towards the anchors of plots 1 and 2.
The anchors of plot No. 3 (transect No. 7) lie along the first axis between the second and third quadrant with Pinus roxburghii and Indigofera dosna as main species. The transitions point clearly towards these anchors, the slide sections towards the transitions. According to the frequency table, the vegetation here has obviously become denser with Pogo-

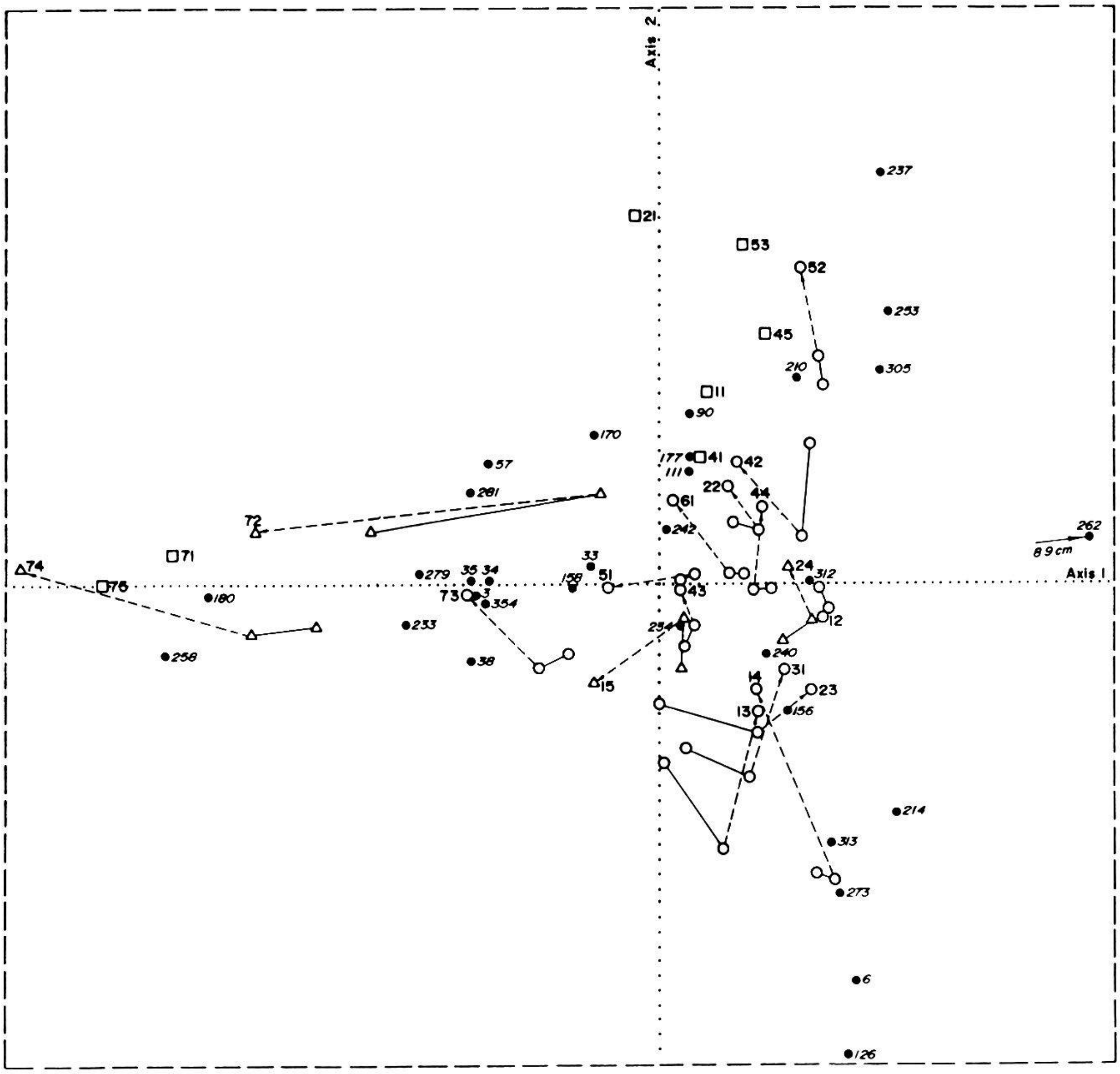


Fig. 4.33. Ordination of postmonsoon records (1983, 1984, 1985).
Group 1: Development and change.

Abb. 4.33. Ordination der Aufnahmen nach dem Monsun (1983, 1984, 1985).
Gruppe 1: Entwicklung und Veränderungen.

Anchor □ 335
Transition △——△- - -→△ 302 Transect No.
Slide ○——○- - -→○ 31 Section in transect
(year) (1983) (1984) (1985)

Species ●288 (for No. and species name see tables 4.1-4.4, 4.6. Species unspecifically concentrated in the centre are not shown)

●← 8.9 cm distance from center

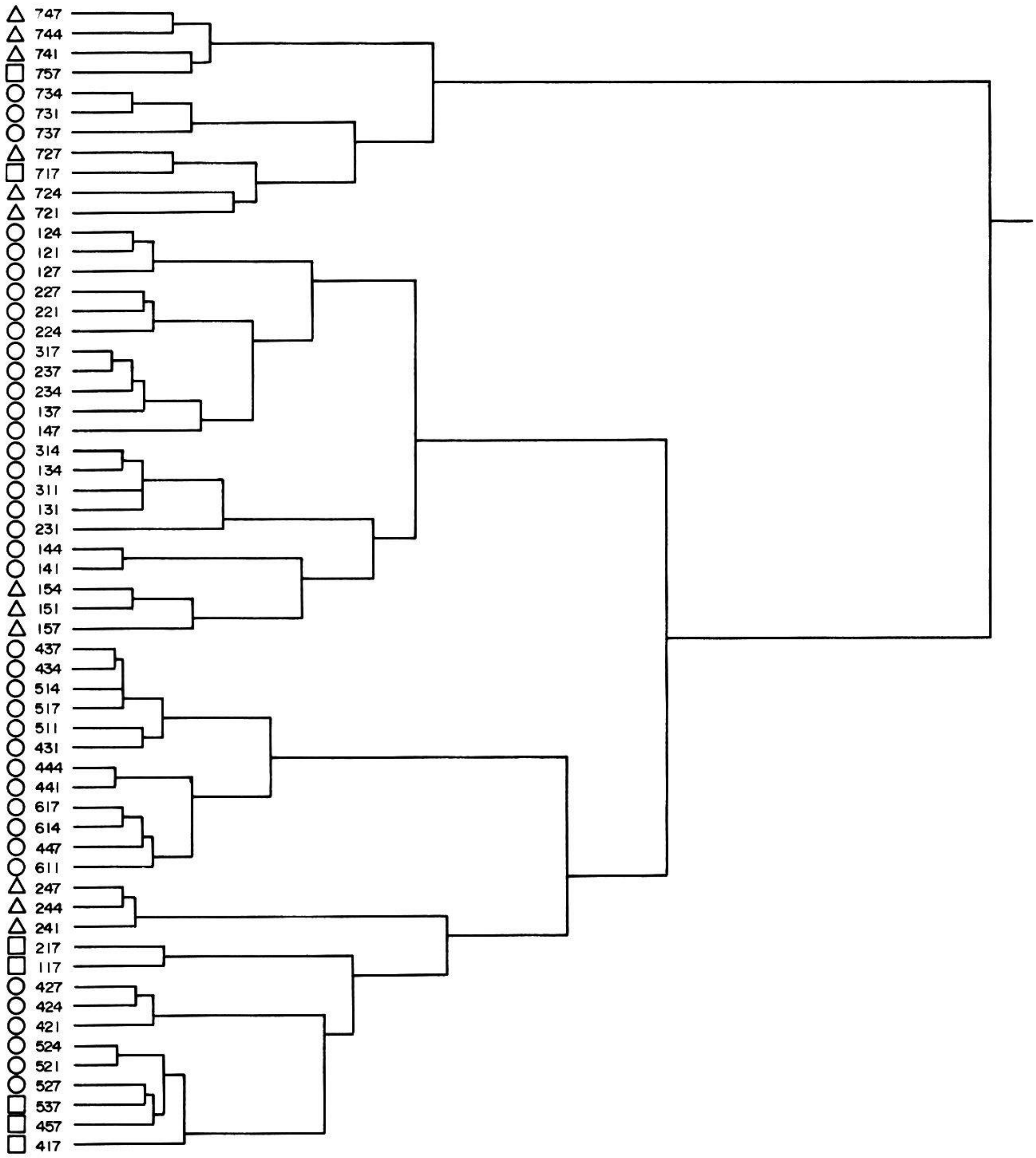
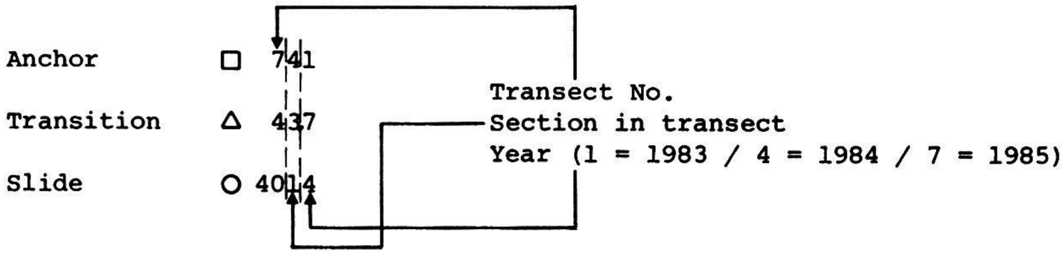


Fig. 4.34. Cluster analysis of postmonsson records (1983, 1984, 1985).
Group 1: development and change.
Abb. 4.34. Dendrogramm der Aufnahmen nach dem Monsun (1983, 1984, 1985).
Gruppe 1: Entwicklung und Veränderungen.



natherum sp., Sacciolepis indica, Brachiaria villosa, Hypericum cordifolium, Biophytum sensitivum, Borreria stricta, Phyllanthus niruri etc.; the regeneration of Pinus roxburghii is striking.

Group 2. Middle altitude with a generally southern aspect.
This group covers 15 plots and therefore yields a wide variety of development trends shown in the scatter diagram (Fig. 4.35).

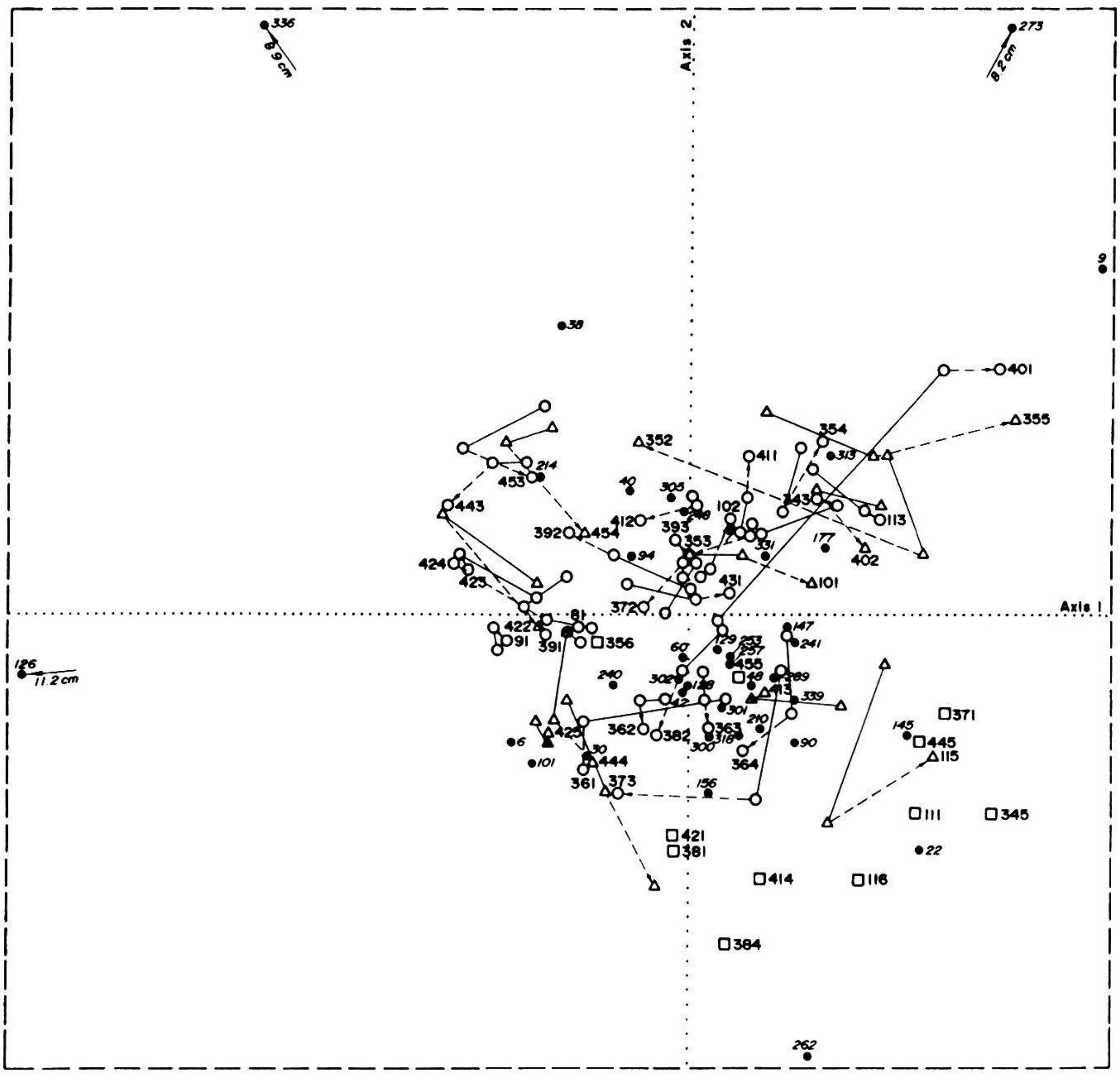


Fig. 4.35. Ordination of postmonsoon records (1983, 1984, 1985)
Group 2: Development and change (for legend see Fig. 4.33)
Abb. 4.35. Ordination der Aufnahmen nach dem Monsun (1983, 1984, 1985). Gruppe 2: Entwicklung und Veränderungen (Legende siehe Abb. 4.33)

The anchors lie mainly in the fourth quadrant with Gaultheria fragrantissima, Lyonia ovalifolia, Gonostegia hirta, Arundinella nepalensis and Dicranopteris linearis as related species. As an exception, anchor 26 (transect 35) lies in the third quadrant, with Alnus nepalensis, Berberis aristata, Osbeckia nepalensis and Drymaria diandra; anchor 28 and 32 (transects 38 and 42) lie along the second axis between the third and fourth quadrant.

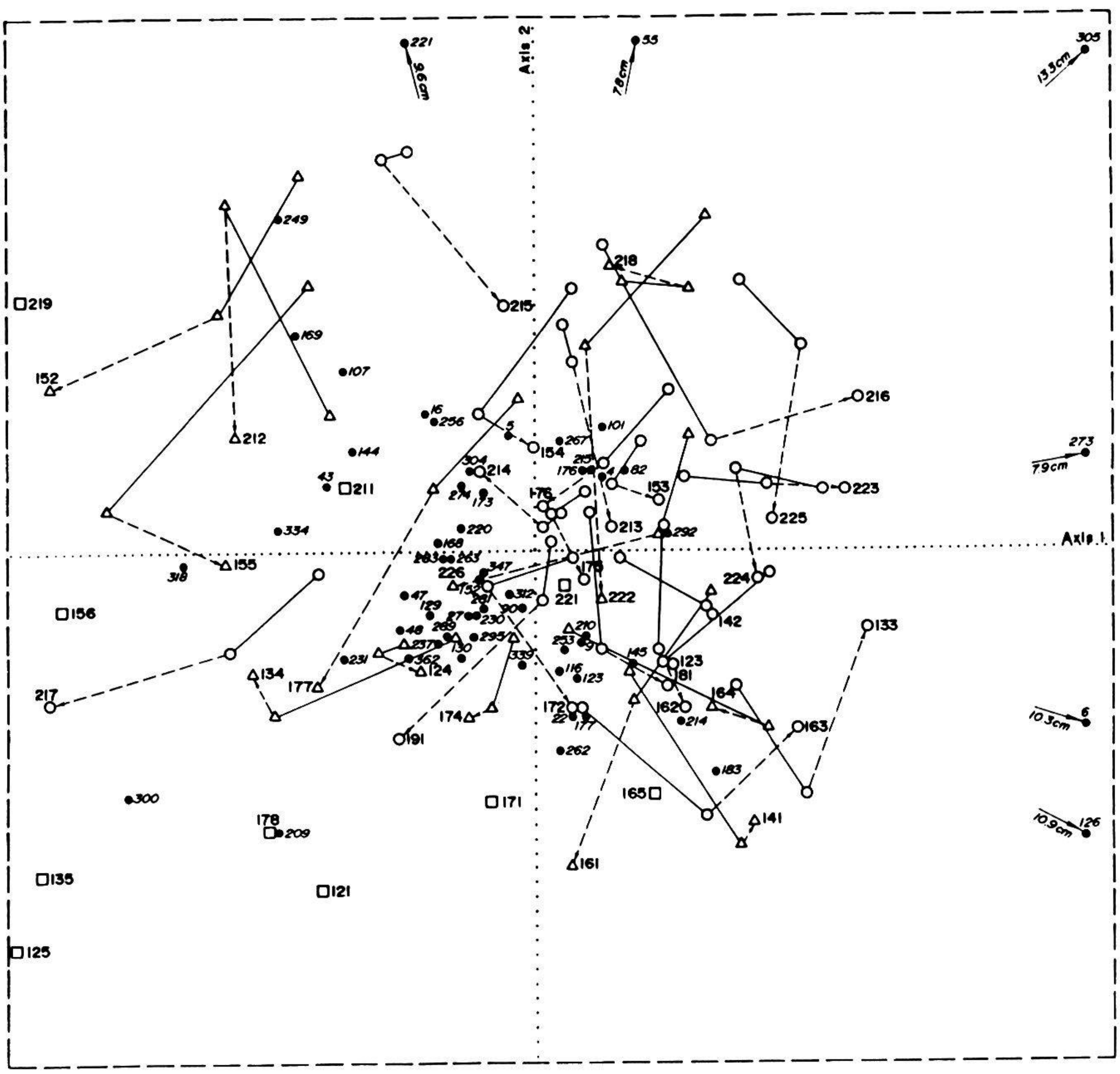


Fig. 4.36. Ordination of postmonsoon records (1983, 1984, 1985).
Group 3: Development and change (for legend see Fig. 4.33)

Abb. 4.36. Ordination der Aufnehmen nach dem Monsun (1983, 1984, 1985).
Gruppe 3: Entwicklung und Veränderungen (Legende siehe Abb. 4.33)

The other sections are very scattered over the diagram, but some trends can be stated:
The transitions - lying in all four quadrants - remain somewhat peripheral. Those in the third quadrant are grouped around Alnus nepalensis, Berberis aristata, Osbeckia nepalensis and Drymaria diandra. The transitions of Nos. 28 and 34 (transects 38 and 44) indicate a trend towards the anchors 28 and 32. No. 7 moves definitely towards anchors 7, 31 and 34 (transects 11, 41 and 44) and transitions No. 31 towards anchor 35 (transects 41 and 45). Transitions 29 and 35 (transects 39 and 45) are directed towards anchor 26 (transect 35).
The slope sections also lie in all four quadrants. They point in all directions, in general tending towards the peripheral transitions.

Group 3. Middle altitude with a generally northern aspect.
The scatter diagram of the three postmonsoon records of group 3 is given in Fig. 4.36.
The anchors lie mainly in the third quadrant with Eurya spp., Neillia thyrsiflora, Carex spp., Lycopodium clavatum, Selaginella sp. and Ptychanthus striatus as the main related species. Exceptions are plots No. 14 (transect 21) with the anchors in the second quadrant, and No. 20 (transect 28) plus the anchor of No. 11 (transect 16) in the fourth quadrant with Alnus nepalensis.
To some extent most of the transitions tend towards the anchor group. The trend of the slide sections is less clear. However there is an accumulation of slide sections in the first quadrant with a general tendency towards the different transitions.

Group 4. High altitude.
The scatter diagram (Fig. 4.37) of the postmonsoon records of group 4 shows the following situation:
The anchors lie in the second quadrant with Quercus semecarpifolia, Fragaria sp., Strobilanthes atropurpureus and Oryzopsis lateralis as main related species. There are a few exceptions: the anchor of plot No. 21 (transect 29), a well diversified grassland with Elsholtzia pilosula, Hemiphragma heterophyllum, Potentilla fulgens, Agrostis pilosula, Arundinella hookeri and Tripogon filiformis, lies in the fourth quadrant; anchor No. 24 (transect 33), a badly overexploited forest on wet ground, lies in the third quadrant with Chambainia cuspidata, Eupatorium adeno-

phorum, Galium sp. and Selaginella sp. as related species; the second anchor of No. 17 (transect 24) lies on the first axis between the second and third quadrant; anchor 1 of transect 30 of plot No. 22 lies along the second axis between the third and fourth quadrant.

The transition sections of Nos. 18, 19 and 21 (transects 25-27 and 29) are situated around anchor 21, the grassland; transitions 16 and 24 (transects 23 and 33) lie near anchor 24. The transitions of No. 22 and 23 (transects 30-32) point towards Quercus semecarpifolia.

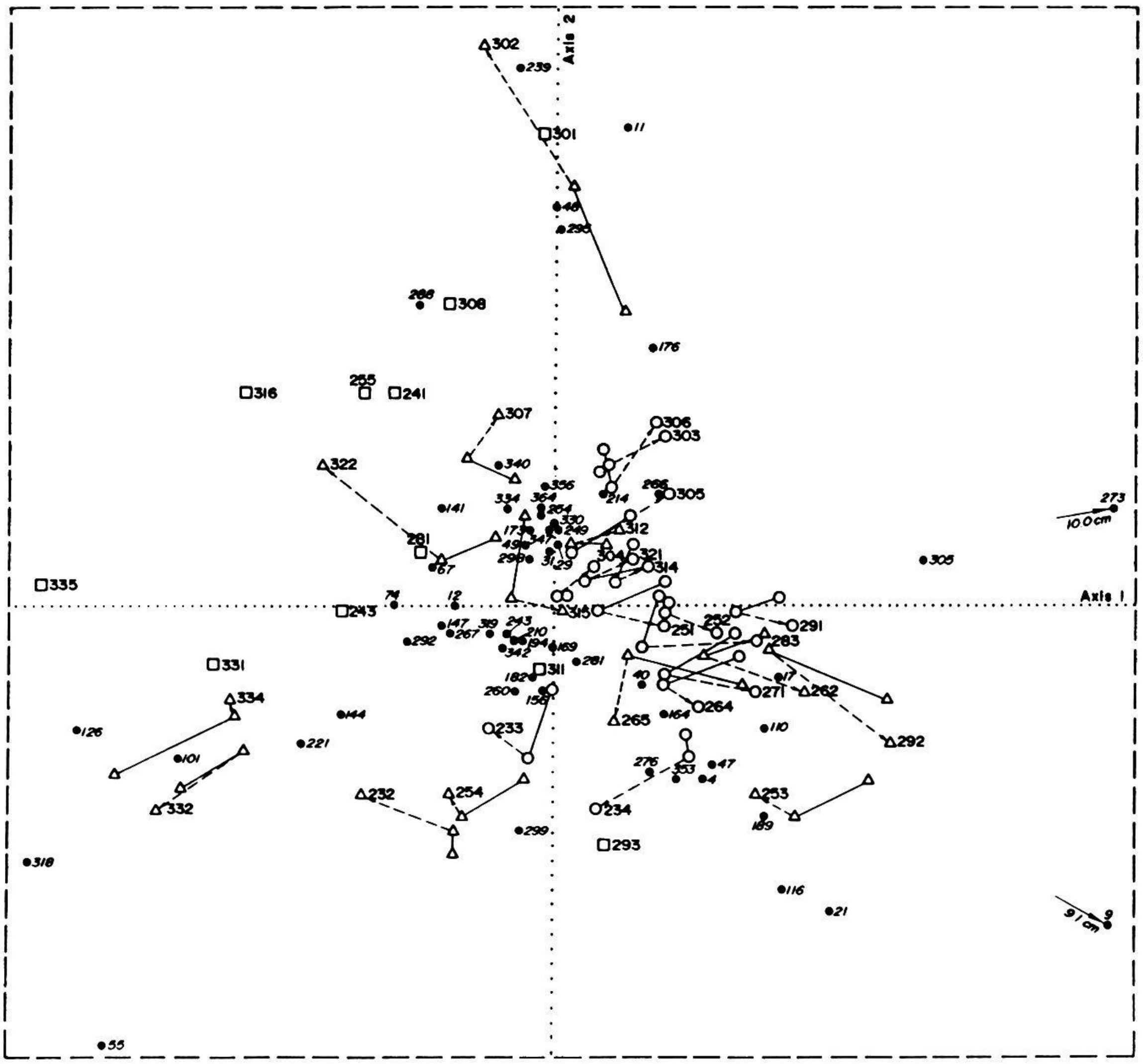


Fig. 4.37. Ordination of postmonsoon records (1983, 1984, 1985).
Group 4: Development and change (for legend see Fig. 4.33)

Abb. 4.37. Ordination der Aufnahmen nach dem Monsun (1983, 1984, 1985).
Gruppe 4: Entwicklung und Veränderungen (Legende siehe Abb. 4.33)

The slide sections 22 and 23 (transects 30-32) are grouped in the first quadrant; they do not show a strong tendency but only a slight upward-trend towards Impatiens racemosa and Anaphalis triplinervis. Slide sections 16 and 18-21 (transects 23 and 25-29) lie in the fourth quadrant; a development towards the transition sections 18-21 (transects 25-29) is visible. One slide section of No. 16 (transect 23) is definitely moving towards anchor 21 (transects 29), the other section of No. 16 lies in the third quadrant pointing towards anchor 24 (transect 33).

4.2. SOIL RESEARCH

The examination of the soil profile of each plot is supported by the detailed soil survey of the Lamosangu-Kharidhunga region by ESPINOSA (1974, 1975). A more rough and general analysis of the soil with chief importance on stability problems was done by LJRP (1977). Fig. 4.38 shows the soil associations of the Lamosangu-Kharidhunga area as evaluated by ESPINOSA; Tables 4.11 and 4.12 (in the pocket of the cover) by the same author give closer information on the soils found there. A summary of the field-data and the analytical data of the laboratory tests with an attempt to integrate these data in ESPINOSA's classification

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Fig. 4.38 (p. 71). Soil associations of Lamosangu-Kharidhunga area (after ESPINOSA 1975) (see also Table 4.13)
Abb. 4.38 (S. 71). Bodengruppen im Gebiet von Lamosangu-Kharidhunga (nach ESPINOSA 1975) (vgl. auch Tab. 4.13)

Soils of bench terraces:
1 Birta Besi - Birta Pakhar association
2 Dhuseni - Kathaike - Lapse association
3 Dhuseni - Golme Danda - Sukjani - Lapse association
4 Tauthali - Kathaike association
5 Sarai Danda - Sarangthali - Chitre - Burani association
6 Kharidhunga - Mane association
Soils of dissected hilly and mountainous lands:
7 Golme Danda - Deorali association
8 Sarai Danda association
9 Kaping and Guchchhe undifferentiated group
10 Sarai Danda, Golme Danda and Guchchhe undifferentiated group
Gullied land


Charikot
Halaule Khola
Tauthali Khola
Kodari
Lamosangu
Dandapakhar
Pakhar Khola
Sun Kosi River
Kathmandu

(see FAO-UNESCO 1974 and FAO 1977) is included in Table 4.13 (in the pocket of the cover) and in Table 4.14.

For the anchor sections the main soil groups are the Cambisols (dystric, humic and a few chromic) and the Acrisols (orthic and humic). Over the whole range of altitude there are obviously many transition stages not easily to interpret both in and between the two soil-groups, especially between orthic Acrisol and dystric Cambisol. The slide sections consist for the most part of dystric Regosols or - mainly on slopes cut because of road-construction - of Lithosols (as example see Figs. 4.21, 4.22). With the exception of slides 11 and 12 no measurable $CaCO_3$-content was found.

In general the pH-value is low. The discrepancy between the values measured on site and in the laboratory can be explained on the one hand by the use of different mediums to measure with and on the other hand by the circumstances in which the measuring took place: The augering and direct determination of the pH-value (Hellige) was undertaken in April when vegetation growth starts and the high CO_2-content then caused by plants and micro-organisms lowers the pH of a soil. The samples for the laboratory tests however were dug at the end of June after the start of the monsoon. They were then air-dried (which raises the pH slightly due to CO_2 escaping) and sent to Switzerland for further analysis; only there the pH(H_2O)-value was measured.

Table 4.14. Exchangeable cations and cation exchange capacity of selected soils

Tab. 4.14. Austauschbare Kationen und Kationen-Austauschkapazität in ausgewählten Böden

Plot No.	Exchangeable ions (m al/100 g soil)				CEC (mval/100 g soil)
	H^+	Ca^{2+}	Mg^{2+}	K^+	
s3	4.6	1.9	0.1	0.1	6.7
s4	8.5	1.9	0.8	0.3	11.5
s9	14.1	2.0	0.1	0.4	17.7
s11	7.5	0.9	0.1	0.1	8.5
s12a	14.4	7.7	1.6	0.4	24.1

4.3. EROSION RESEARCH

4.3.1. Meteorological data

A comparison of the climatograms of Dandapakhar, Bonch and Kirantichap for the years 1983-1985 with the corresponding climate diagrams (Fig. 4.39) demonstrates the following:
The monsoon rainfall started very late in 1983. Therefore only about 30% of the normal rainfall with much sunshine was registered for June. The

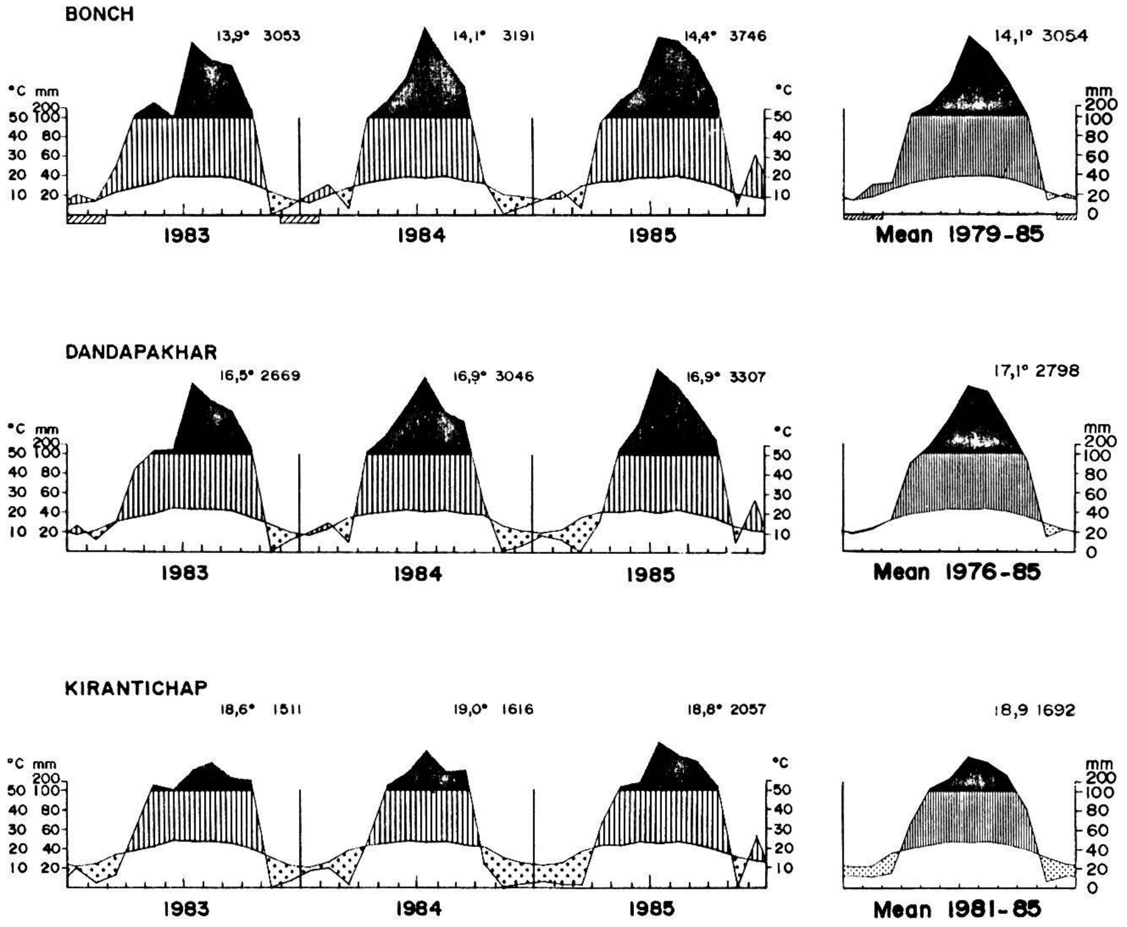

Fig. 4.39. Climatograms of study area, in comparison with climate diagrams (drawn by U. Schaffner, Emmenbrücke; IHDP-data) (for legend see Fig. 2.3)

Abb. 4.39. Klimatogramme aus dem Untersuchungsgebiet, im Vergleich mit den Klimadiagrammen (gezeichnet von U. Schaffner, Emmenbrücke; IHDP-data) (Legende siehe Abb. 2.3) rainy season lasted longer than usual. September had about 150% of the mean rainfall and October about 200%. The monsoon ended in the middle of October. The following dry season was fairly normal, with no rain in November and quite a dry March 1984. There was above average rainfall during May, June and July, and below average rainfall in August. The monsoon gradually ceased in September. There followed a very dry season from November to March 1985 with only about 50% of the normal rainfall. This dry period continued in Dandapakhar with only 30% of the mean rainfall in April. In June again less rain than usual was registered, but July was very rainy; Dandapakhar had the wettest July since 1976. A wet August and September and a very rainy October with more than 300% of the mean rainfall followed.

4.3.2. Station Dandapakhar

Monthly runoff, soil loss figures and rainfall erosivity of the two testplots for 1984 and 1985 are given in Figures 4.40 and 4.41. The total erosivity varies between 1471.5 in 1984 and 1621.2 (Joules·cm/m^2·h·100) in 1985 (Table 4.15, in the pocket of the cover).
The recording raingauge was not working well for some days in July 1984 and for short periods from July to September 1985; on these occasions the hand-measured data taken from the simple raingauge - only measuring the amount of rain - were used for the calculation, with an estimation of the intensity.
Testplot 1, bare, experienced a total soil loss of 16.2 t per hectare in 1984. In 1985 the total soil loss was only 5.4 t per ha. Runoff figures are 5598 m^3 per ha or 18.7% of the rainfall in 1984 and 2454 m^3 per ha or 7.8% in 1985 (Table 4.15, in the pocket of the cover). The marked stones with an average diameter of 5 to 10 cm did not move down. The weekly weeding indicated a strong capacity for natural regrowth of plants. Table 4.16 gives an overview of the species which were removed most frequently. Compared with the surrounding unprotected area a certain stabilization took place thanks to the fence installed around the plot in April 1984.
Testplot 2, overgrown, experienced a total soil loss of 3.3 t per ha in 1984. In 1985 this was reduced to only 0.4 t per ha. Runoff figures are 5303 m^3 per ha or 17.7% of the rainfall in 1984 and only 277 m^3 per ha

or 0.8% in 1985 (Table 4.15, in the pocket of the cover). The plants grew well; there was a significant difference in the density of the plant cover between testplot 2 and the unprotected area outside the fence (Figs. 3.2, 3.3). Composition of plants in testplot 2 and their abundance are listed in Table 4.5 (stable area s3).

It should be taken into consideration that the soil of testplot 1 was loosened regularly by the weekly weeding. Even if done carefully, it might have increased the soil loss. But nevertheless the definitely lower soil loss and runoff on testplot 2 clearly shows the protecting power of plant cover on slopes.

Table 4.16. Testplots 1, bare: most frequent removed species
Tab. 4.16. Testflächen 1, kahl: die am häufigsten gejäteten Arten

Dandapakhar	Bonch
Eupatorium adenophorum	Berberis aristata
Hypericum cordifolium	Eupatorium adenophorum
Osbeckia nepalensis	Phyllanthus parvifolius
Phyllanthus parvifolius	Arthraxon lancifolius
Arundinella nepalensis	Arundinella nepalensis
Cynodon dactylon	Eragrostis papposa
Digitaria ascendens	Imperata cylindrica
Digitaria violascens	Pogonatherum crinitum
Eragrostis unioloides	Saccharum spontaneum
Schizachyrium brevifolium	Sacciolepis indica
Sporobolus piliferus	Schizachyrium brevifolium
Fimbristylis dichotoma	Sporobolus piliferus
Cyanotis vaga	Cyanotis vaga
Ageratum conycoides	Ageratum conycoides
Bidens pilosa	Anaphalis contorta
Drymaria diandra	Crotolaria albida
Euphorbia hirta	Euphorbia hirta
Gonostegia hirta	Gonostegia hirta
Micromeria biflora	Selaginella sp.
Polygonum spp.	Moss spp.
Selaginella sp.	
Pogonatum spp.	

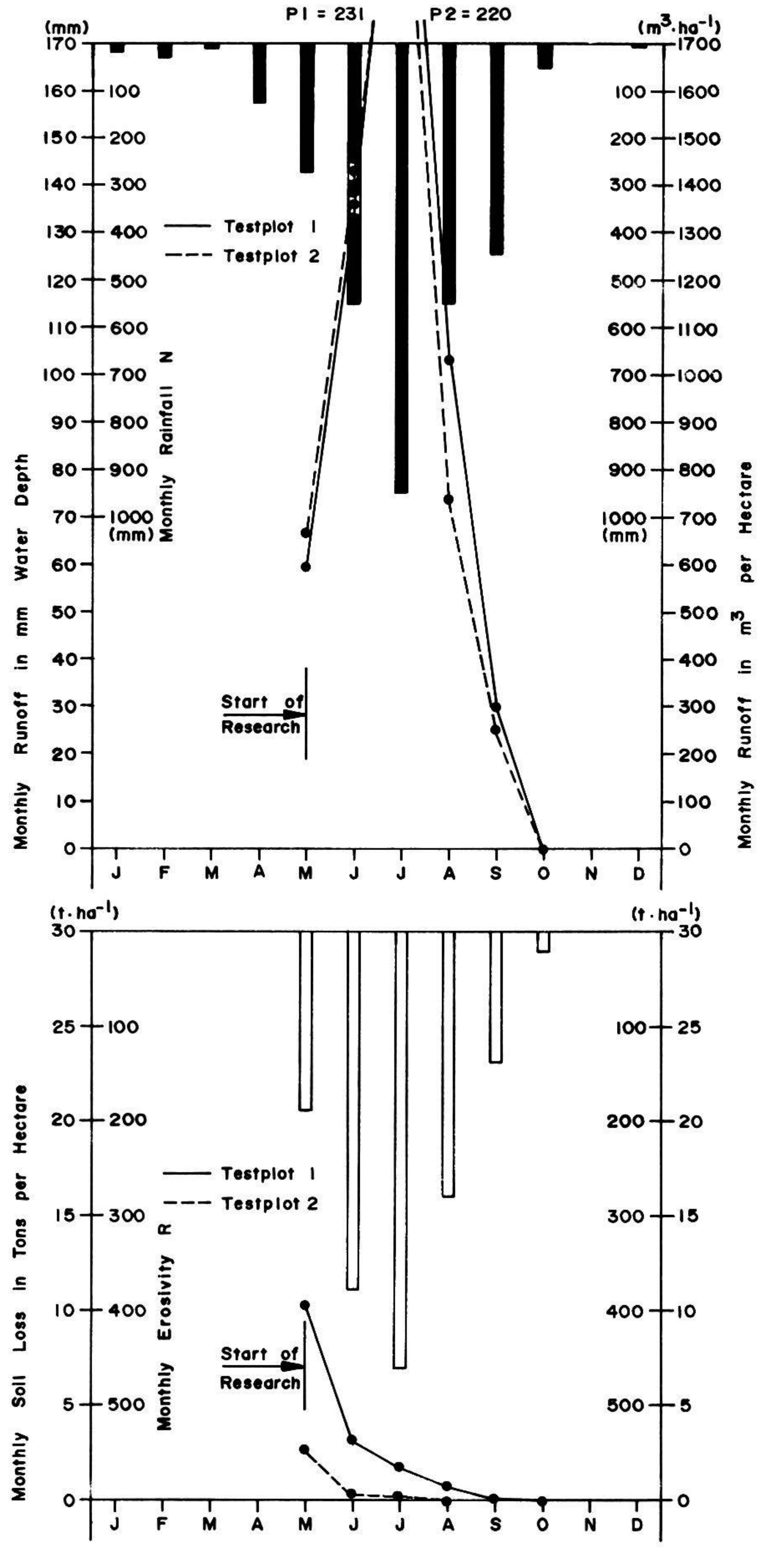

Fig. 4.40. Monthly rainfall, erosivity, runoff and soil loss: Testplots 1 and 2 at Dandapakhar, 1984

Abb. 4.40. Monatlicher Niederschlag, Erosivität, Abfluss und Boden-Abtrag: Testflächen 1 und 2 in Dandapakhar, 1984

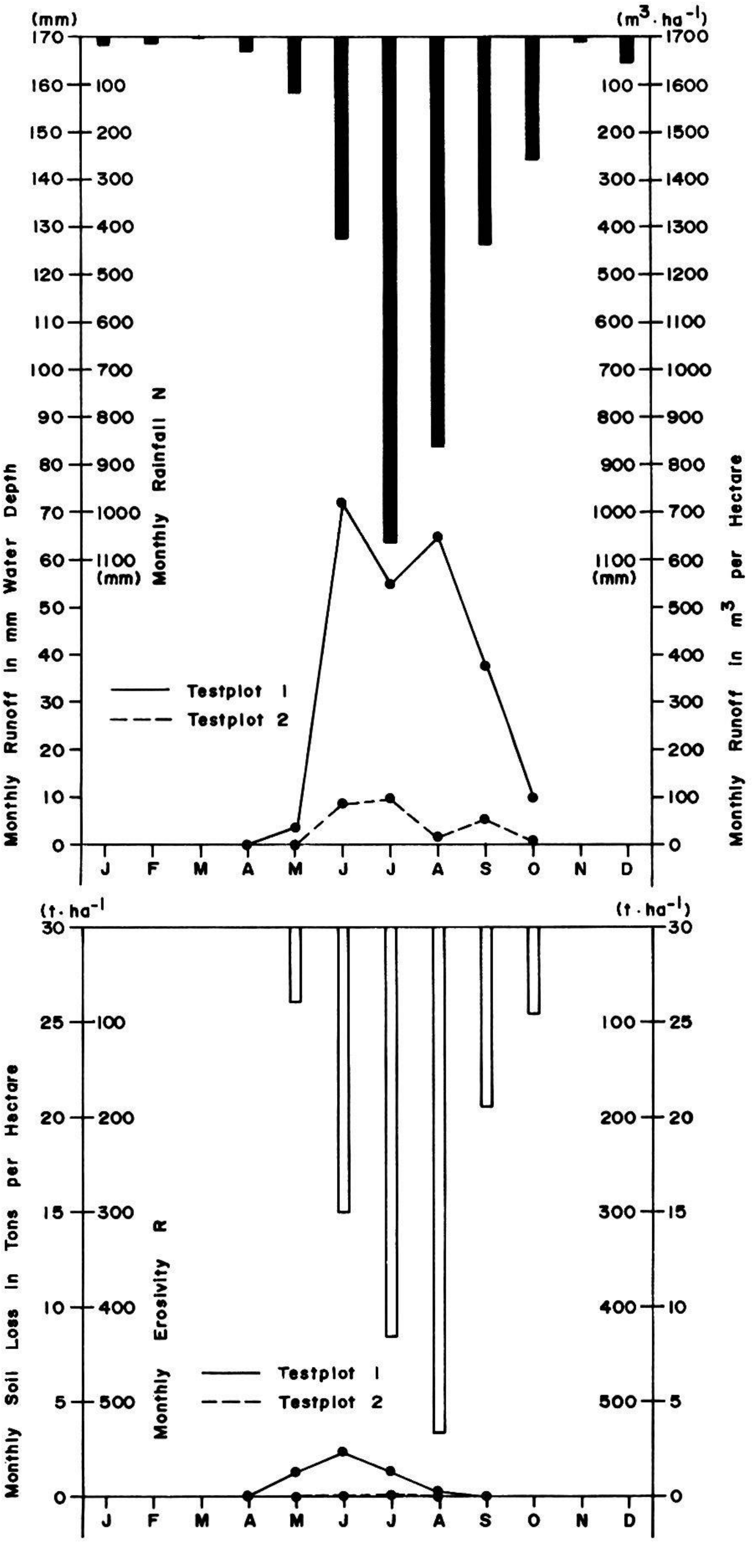

Fig. 4.41. Monthly rainfall, erosivity, runoff and soil loss: Testplots 1 and 2 at Dandapakhar, 1985

Abb. 4.41. Monatlicher Niederschlag, Erosivität, Abfluss und Boden-Abtrag: Testflächen 1 und 2 in Dandapakhar, 1985

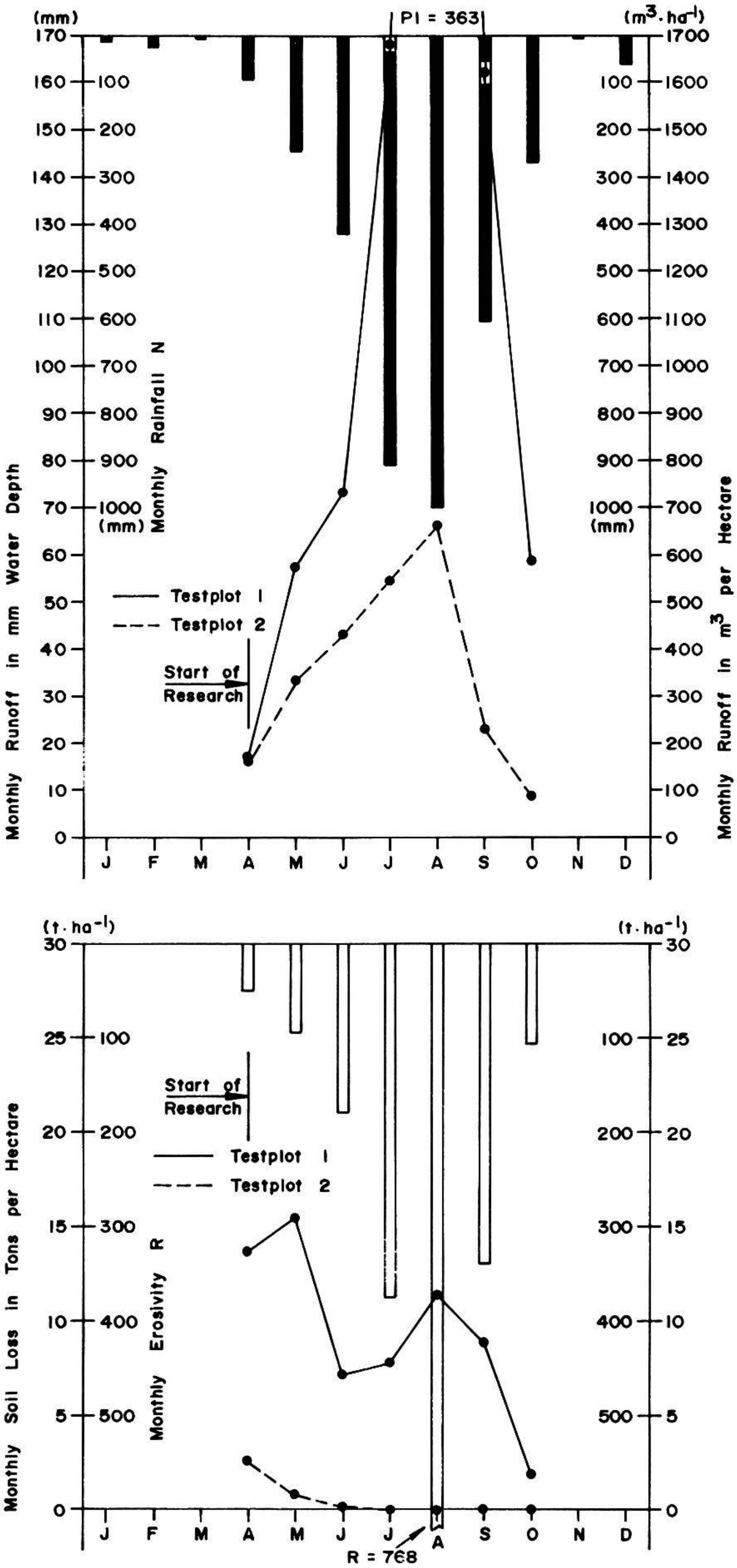

Fig. 4.42. Monthly rainfall, erosivity, runoff and soil loss: Testplots 1 and 2 at Bonch, 1985

Abb. 4.42. Monatlicher Niederschlag, Erosivität, Abfluss und Boden-Abtrag: Testflächen 1 und 2 in Bonch, 1985

4.3.3. Station Bonch

Monthly runoff, soil loss and rainfall erosivity distribution of the two testplots for 1985 are shown in Figure 4.42. The total erosivity is 1912.9 (Joules·cm/m^2·h·100) (Table 4.15, in the pocket of the cover). From September 17-26 the recording raingauge was out of action for clock repair. For this period the data from the simple raingauge - only measuring the amount - were used for the calculations, the intensity was estimated.

Testplot 1, bare, had a high total soil loss of 66.6 t per ha. The runoff was 9001 m^3 per ha, 25.1% of the total rainfall (Table 4.15, in the pocket of the cover). Table 4.16 shows the most frequently weeded species; it gives an idea of the power of natural regrowth.

Testplot 2, overgrown, had only a total soil loss of 3.7 t per hectare. The runoff was 2466 m^3 per ha, which is 6.9% of the total rainfall (Table 4.15). The herb layer covered the plot densely. Table 4.5 (stable area sll) shows the abundance of the species that occurred.

Here too it is evident that dense plant cover decreases runoff and soil loss and thus provides considerable protection against erosion on a steep slope.