Zeitschrift: Veröffentlichungen des Geobotanischen Institutes der Eidg. Tech. Hochschule, Stiftung Rübel, in Zürich

Herausgeber: Geobotanisches Institut, Stiftung Rübel (Zürich)

Band: 93 (1987)

Artikel: Vegetation of stabilizing and eroding slopes in eastern Nepal = Die Vegetation stabilisierender und erodierender Hänge in Ostnepal

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Kapitel: 3: Methods

DOI: https://doi.org/10.5169/seals-308864

3. METHODS

To record the plants, transects were laid through slopes and landslides along the Lamosangu-Jiri Road. The re-covering by plants was observed over a period of three years and the characteristics of each area were examined (Table 3.1, in the pocket of the cover of this volume). From this information an attempt was made to assess the influence of the different interfering factors: Meteorology, altitude, aspect, slope, soil, age of the slope/slide, influence of man and animals.

In addition, at different altitudes a series of surveys was carried out on various relatively stable but not undisturbed types of natural vegetation typical of the region. The floristic composition of the plots examined indicates the possible "climax" to be expected on the slopes in question.

At the same time, special attention was paid to runoff and soil loss in connection with amount and intensity of rainfall and plant cover on steep slopes. The experiments were carried out for one or two rainy seasons at two selected sites typical of the area. On both sites a comparison was made between an uncovered, landslide-like and a plant covered plot and the results are discussed more generally. The data gained also give the first information ever collected about rainfall intensity (erosivity), rainfall runoff and amount of soil loss in the project-region.

3.1. PHYTOSOCIOLOGICAL DATA

3.1.1. Transects

In order to record plant occurrence and succession, 45 fixed transects were laid through 35 landslides or slopes of different age (natural or man induced) representing various successional stages at an altitude of 1000 to 2600 m along 50 km of the Lamosangu-Jiri Road (Table 3.1 in the pocket of the cover of this volume, Fig. 3.1). The plots were examined over three years, that is in early monsoon (in June/July 1984 and 1985),

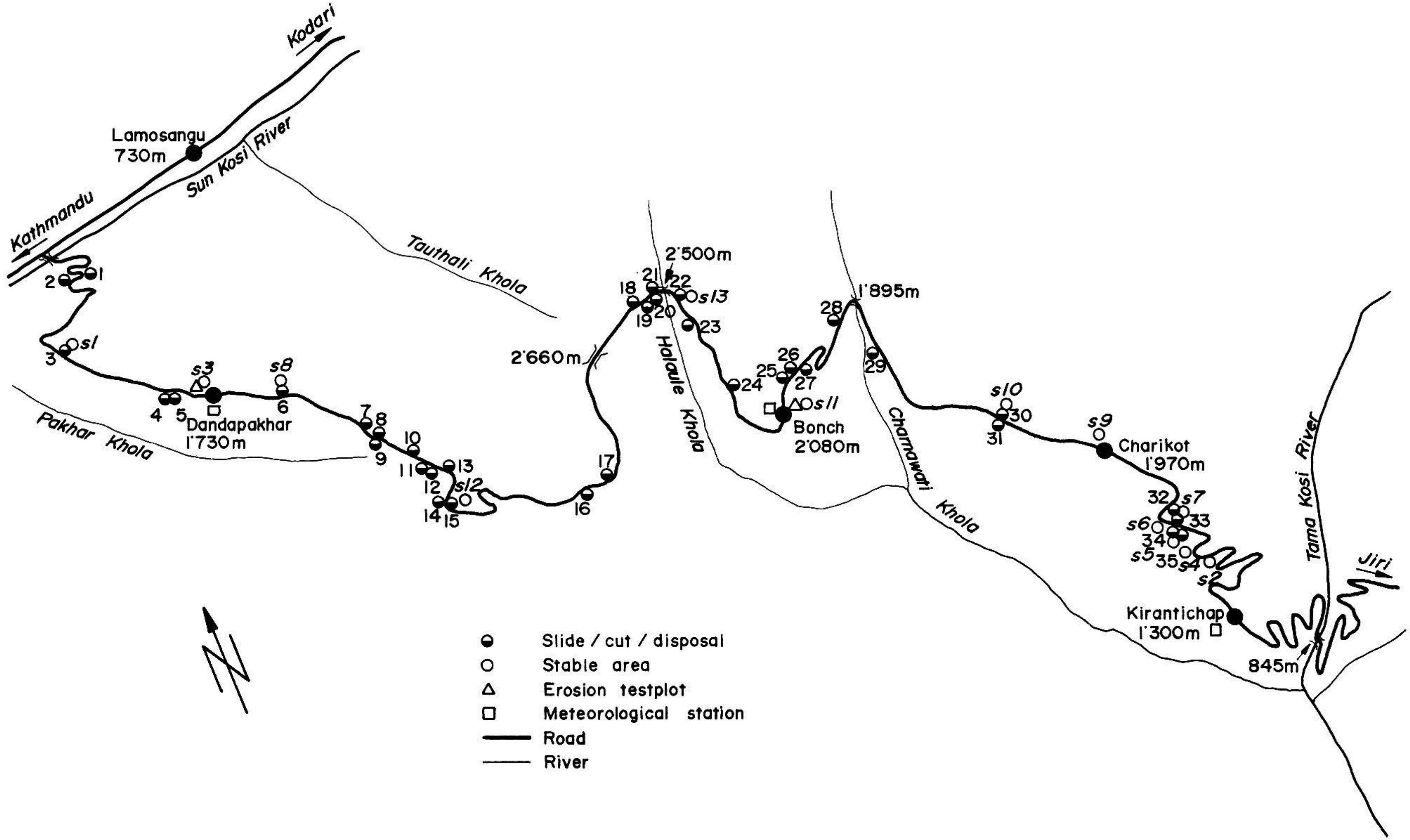

Fig. 3.1. Location of studied plots
Abb. 3.1. Lage der untersuchten Flächen

and after the monsoon (in September/October 1983, 1984 and 1985). A choice of nine of these slopes (Nos. 2, 4, 14, 16, 19, 24, 30 and 34) with quite well-developed plant cover was also checked after the dry season (in April 1984 and 1985).

The method of laying a transect consists in laying out a line which runs across the zone to be sampled and in placing quadrats at given intervals along the line. A frame of pins 10 cm long was used and orientated parallel to the transect at intervals of 20 cm. In each square of 10 cm it was noted which plant species occurred, but not how abundant they were, nor their size or age. The records of the squares of the transect or a section of it were added and the percental frequency was determined.

Theoretically, a transect is composed of an anchor (that is the relatively stable part on both sides of the landslide), the actual landslide and the transition between anchor and slide. Since an anchor or transition does not exist everywhere and the landslide may not be homogenous but composed of sections of a different age, it was not always possible in practice to lay the transects according to the above pattern. The placing of sections was provisionally fixed on site and was later revised according to the data collected by comparing plant occurrence in the "pufferung zone" (the semistable zone, where erosion is stopped, and which helps initiate further stabilization), as described for vegetation tables in MUELLER-DOMBOIS and ELLENBERG (1973).

Usually one horizontal transect per plot was laid. On plots 8, 22 and 33 two horizontal lines were recorded; on plot No. 19 one vertical and one horizontal line; on plots 1, 2 and 11 one vertical and two horizontal lines. The vertical transects give good homogenity for the slide section.

3.1.2. Evaluation

The large amount of data collected made it necessary to use a computer for the mathematical processing. The FORTRAN-IV program package described by WILDI and ORLOCI (1983) was used; the program names referred to are those used by these authors.

In view of the wide range of site factors and the heterogenity of vegetation it was first necessary to divide the plots into appropriate groups. This was done separately for the three sections, i.e. anchor,

transition and slide of the last postmonsoon records (October 1985), each section being treated as a relevé. Rare species occurring only once or twice were eliminated as were very abundant species occurring unspecifically over the whole study area, in order to clarify the group structure. The ordination co-ordinates of the relevés and species were computed by correspondence analysis (program PCAB). This allows a direct comparison of relevés with species and aids in assessing their interaction. The corresponding scatter diagram was printed (program ORDB).
By calculating the correlation coefficients (program RESE) the influence of the site factors could be determined. The following discriminant analysis (program DIAN) allowed confirmation of the group pattern and analysis of the discriminating power of the site factors for the relevé groups.
For each site group and its sections a minimum variance cluster analysis (program CLTR, using the cross product matrix of RESE) was computed in order to find species group structures. Then a frequency table was printed (program TABS).
In order to get a general idea of development trends and potential stabilization, the postmonsoon records of the years 1983, 1984, 1985 of each site group were compared. With the help of the correspondence analysis (program PCAB) and the following ordination (program ORDB) the respective scatter diagrams were printed. The points representing the same relevés were chronologically connected by arrows. From the same diagram the various successional stages of the sections can be noted. In addition, the data were processed by minimum variance cluster analysis and the corresponding tables were printed (program CLTR and TABS).
By the same method the records of the end of the dry season (April 1984 and 1985) and then those of the early monsoon (June 1984 and 1985) were computed for further comparison to confirm the findings of the postmonsoon records.

3.1.3. Stable Areas

The natural vegetation of relatively stable areas was recorded. They range from forest to shrubland to grassland or pasture. This gives additional knowledge of the floral composition of the study areas and allows a comparison with the plant occurrence in the three sections of the transects in the slopes and landslides of the study.

Table 3.2. The stable areas and their site charateristics
Tab. 3.2. Die intakten Gebiete mit ihren Standortsfaktoren

Stable area	Vegetation type	Altitude a.s.l.	Aspect 0-400°	Slope %	Location	Group No.
s1	xerophilous Pinus roxburghii-forest	1450	225	80	Thumpakhar	1
s2	xerophilous Pinus roxburghii-forest	1570	225	40	Daramghar	1
s3	shrubland	1700	225	65	Dandapakhar	2
s4	mesohygrophilous forest with Schima wall., Castanopsis ind., Rhododendron arb.	1710	300	60	Mati	2
s5	mesohygrophilous forest with Schima wall., Castanopsis ind., Rhododendron arb.	1730	250	80	Mati	2
s6	Eupatorium-shrubland	1740	200	35	Mati	2
s7	Eupatorium-shrubland	1750	175	70	Mati	2
s8	mesohygrophilous forest with Schima wall.	1820	250	75	Thulopakhar	2
s9	Imperata-pasture land	2050	150	30	Charikot	2
s10	Eupatorium-shrubland	2050	300	75	Makaibari	2
s11	grassland	2100	200	70	Bonch	2
s12a	hygrophilous forest with Daphniphyllum himalayense	2150	400	60	Shildhunga	3
b		2150	300	65		
c		2270	150	45		
d		2280	150	45		
s13	mesohygrophilous forest with Quercus seme-carpifolia	2600	250	75	Halaule Khola	4

In 13 typical areas throughout the project region (Fig. 3.1, Table 3.2) the species present within a sample plot were listed, and to each species the following subjective assessments of abundance (simplified according to Braun-Blanquet's system of rating, compare e.g. KERSHAW 1973) were attached:

+ scarcely or only one present
1 covering less than 5% of the area
2 covering 5 to 25% of the area
3 covering 25 to 50% of the area
4 covering 50 to 75% of the area
5 covering 75 to 100% of the area.

Four layers were fixed: Trees (3-40 m), shrubs (1-3 m), herbs (0-1 m) and mosses.

The plots were characterized by their plant cover, site, altitude, bedrock, aspect, slope, size of area and influence of man (DOBREMEZ 1974b, KANAI et al. 1975).

3.1.4. Identification of Plants

The collected plants were identified in the National Herbarium of Nepal (Department of Medicinal Plants). Where it was uncertain the skilled staff made invaluable specifications. For the nomenclature the "Catalogue of Nepalese Vascular Plants" (MALLA 1976) of the same institute was used.

Since there is no moss-collection in the Herbarium in Nepal, the collected moss-species were brought to Switzerland. They were identified by Dr. Patricia Geissler in the Herbarium of Geneva.

3.2. SOIL

3.2.1. Soil Analysis

A mixed soil sample from the upper 20 cm of each anchor and slide of all the plots was taken. The 101 samples were air-dried and separated by

sieving. The 2 mm-fractions were sent to the Swiss Federal Research Station for Agronomy, Zürich. There the pH(H_2O)-value was measured and the content of phosphorus (P_2O_5) and potassium (K_2O) was analysed (in CO_2-saturated water, method of Dirks-Scheffer). The texture-class and humus-content of all the samples were estimated.
21 samples were further analysed for particle size distribution (sedimentation analysis) and organic carbon-content (wet incineration with potassium bichromate) and for 5 samples the cation exchange capacity was measured (in an exchange solution with an extraction mixture of 0.1N HCL and 0.05N H_2SO_4 1:1).

3.2.2. Soil Profile

Soil and bedrock-samples from each plot (slope/landslide/stable area) were examined. A rough division of the ground was made on site (rubble/unstabilized scree slope/technical stabilization/soil/rock).
On each site the soil profiles of the anchor and slide section were determined by boring a hole, observing structure, colour and consistency and measuring pH-value (Hellige) and presence of $CaCO_3$. The soils were characterized by comparing the profiles with those given in the soil study of ESPINOSA (1975), by using the nomenclature of FAO-UNESCO, Soil Map of the World (1974).

3.3. EROSION RESEARCH

3.3.1. The testplots

Soil and water loss is mainly influenced by rainfall (intensity and duration), vegetation cover, type of soil, inclination, length and shape of slope. To get individual storm runoff and soil loss data in the study region, two erosion control stations were installed.
The testplots at Dandapakhar (1730 m a.s.l.) (Figs. 3.2, 3.3) lie 200 m away from the meteorological station of IHDP and 15 m higher. They were under observation from May 1984 till October 1985. The two testplots lie

Fig. 3.2. The testplots at Dandapakhar on June 14, 1984
Abb. 3.2. Die Untersuchungsflächen in Dandapakhar am 14.6.1984

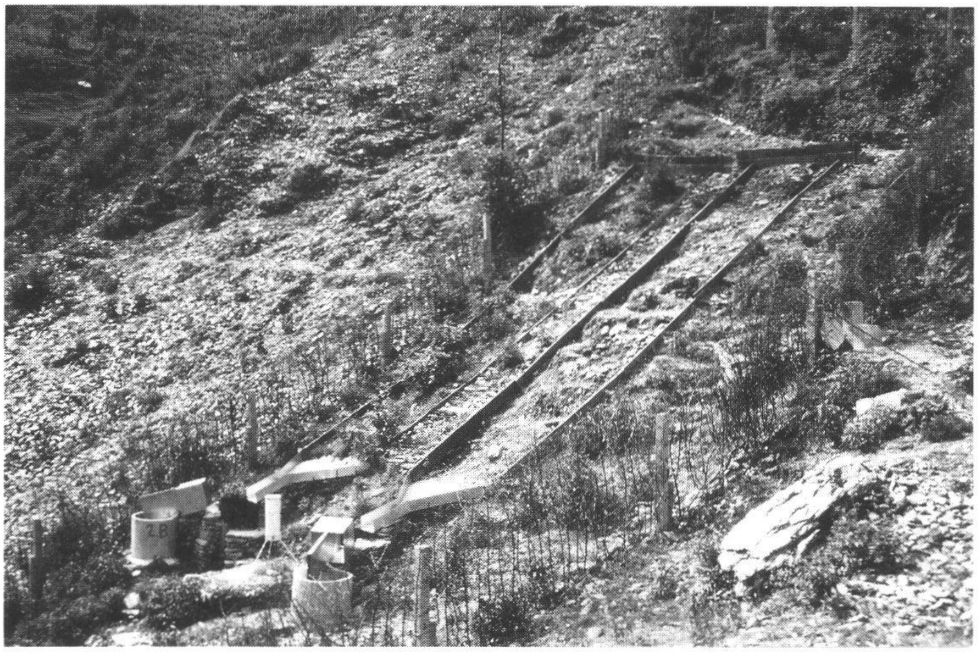

Fig. 3.3. The testplots at Dandapakhar on October 15, 1985
Abb. 3.3. Die Untersuchungsflächen in Dandapakhar am 15.10.1985

on a SSW-facing, 65% slope of an old landslide which was afforested with <u>Pinus roxburghii</u> by IHDP in 1983. The rock material of the slope consists of grey phyllitic schist and the rock dip lies nearly parallel to the slope surface. The whole landslide moved downwards about 1 m in September 1984 and is still moving slightly. Because of this downward shift the lower part of the overgrown plot was damaged and tank A was slightly tilted. This was repaired during the following dry season.

On the testplots at Bonch (2080 m a.s.l.) (Fig. 3.4) measurements were taken from April to October 1985. The site lies 250 m away from the meteorological station of IHDP and 50 m lower. It faces SSE on the well-covered 70% slope of an old gully. The whole area has been protected by a fence since 1980 as it belongs to an IHDP Subcenter. The bedrock consists of profoundly weathered schistoid gneiss (WAGNER 1983).

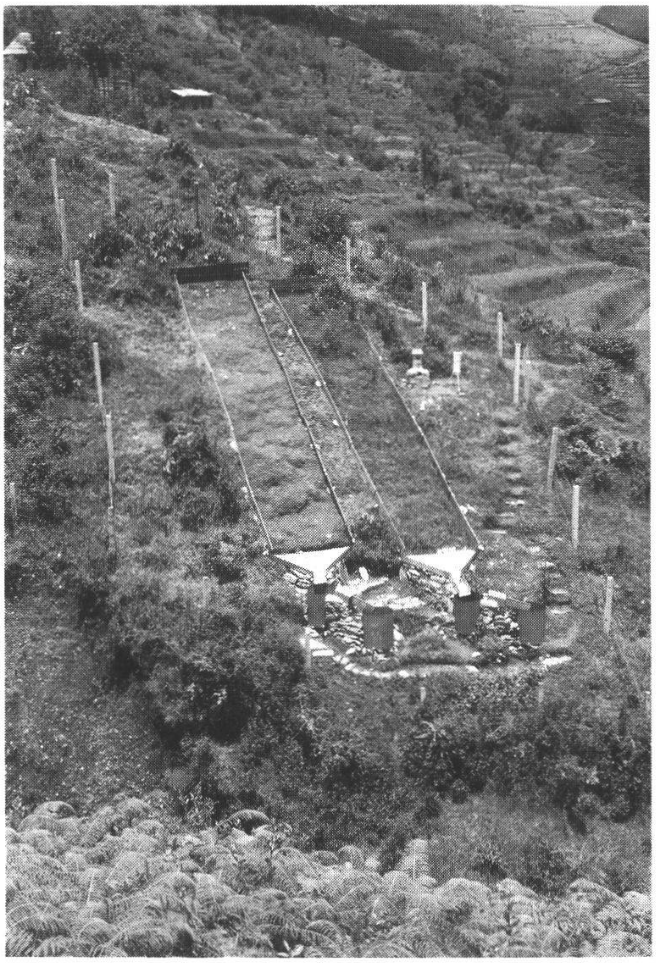

Fig. 3.4. The testplots at Bonch on August 5, 1985
Abb. 3.4. Die Untersuchungsflächen in Bonch am 4.8.1985

3.3.2. Experimental Design and Measurement

Of the common models available we chose to use that of the Soil Conservation Research Project in Ethiopia (SCRP 1984 and HURNI in prep.).
On both sites 2 plots of 20 m^2 (2 m wide and 10 m long) were bounded by wooden planks. One of the plots was left with its natural plant cover, the other one was totally weeded and weeding was repeated once a week. The plants of the overgrown testplot were recorded and on the plot at Dandapakhar the growing rate of the shrubs was measured. At Dandapakhar a choice of stones with a diameter of 5-10 cm were marked and their downward movement was measured. For protection a fence was built around the stations.
A recording raingauge was installed on both sites to measure the intensity of each storm, supported by a raingauge measuring only the total amount of rain as a control measure; these hand-measured data were also used when occasionally the recording raingauge was not working. With the recorded rainfall data the erosivity of each storm was calculated. According to WISCHMEIER and SMITH (1960, 1978) the erosivity indicates the

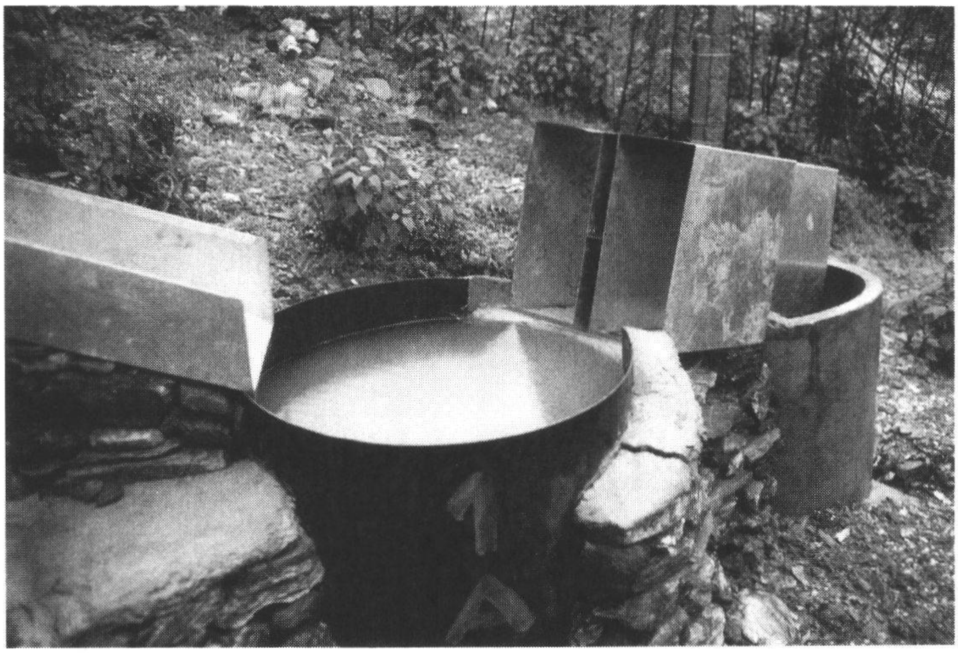

Fig. 3.5. Testplots Dandapakhar: Detail with tank A, overflow to tank B. 1.7.1984
Abb. 3.5. Untersuchungsflächen Dandapakhar: Detail mit Tank A und Ueberlauf zu Tank B. 1.7.1984

value of a storm which is proportional to soil loss on a bare soil continuously lying fallow caused by this storm. Therefore, rainfall erosity will not be proportional to the actual soil loss of a test plot, since vegetation cover, management practices, slope length and gradient are additionally influencing factors (HURNI 1982).

Runoff and sediment were collected into tank A (270 l capacity) through a channel at the lower end of each plot. For possible overflow from tank A a slot divisor, taking only 1/10 of the overflow, led to tank B (Fig. 3.5). After each storm or every morning following a rainy day the water in the testplot tanks was measured and 1-liter samples of tank A and - if there was overflow - of tank B were taken. The weight of the soil in tank A was measured and a soil sample of 500 g was taken (average variation of balance: 9%). The water samples were filtered. The filterpaper and the soil samples were dried for 24 hours at 60-100^{o}C, and the oven- dry weight of the soil contents measured (METTLER balance). The total soil loss and runoff were now calculated (for detailled sampling method and calculation see SCRP 1984, Vol. 1, pp. 30-32 and Appendix 3, and Vol. 2, Appendix 1 and 5).