Preliminary Study of Landform Classification for Sustainable Land Conservation in the Mahabharat Lekh, Nepal

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Abstract Detailed-scale landform classification has been done in the upper Rapti River basin, the Mahabharat Lekh, Nepal. The landform units are categorized crest slope, crest gentle slope, upper and lower side slope, head hollow, channelway, footslope, and bottomland. Two remarkable erosion fronts are identified. One is the convex break which divides the crest proper and valley side proper. The other is distinguished as a margin of surface landslide area, and is almost equivalent to lower side slope. The information is utilized for evaluation of land-surface stability and further for the basic plan of land conservation.

Key words: detailed-scale landform classification, sustainable land conservation, lower side slope, erosion front, Nepal.

1 Introduction

It is required to make a scenario of spatial management in respective scales of space and dimensions of social activities for sustainable land use and conservation.

This research in a preliminary stage intends to clarify natural environmental dynamics of hillslopes, on which geomorphological, hydrological, pedorological processes take place, as a basis of land classification and evaluation in a small drainage basin of the Mahabharat Lekh (Range), Nepal.

"Landform" is considered a key factor of natural environment in making of the scinario which reflects the various physical environmental factors. Landform in sloping area is usually recognized on the bases of some morphometric attributes such as slope angle, curvature, directiion *etc.* Although these attributes may indicate in part of slope stability, they seem insufficient for evaluating more comprehensive landform condition in environmental management. For this purpose, the landform units in each scale should be indentified by shape, material, processes, and age.

This study of sloping landform in detailed scale consists of the following stages, *i.e.*, 1st stage: categorization of topography as a basis of landform unit setting; 2nd stage: clarification of the historical and active processes in geomorphic development,

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particularly massmovement, for establishing landform units, and combining them with land systems ; 3rd stage : evaluation of each landform unit and land system from the viewpoint of sustainable land conservation.

2 Outline of study area

The composition of landforms of the area studied is illustrated in different scales as a schematic cross-section (Fig. 1). The upper half of the figure (cross-section of the Himalaya) is referred after Kizaki (1988).

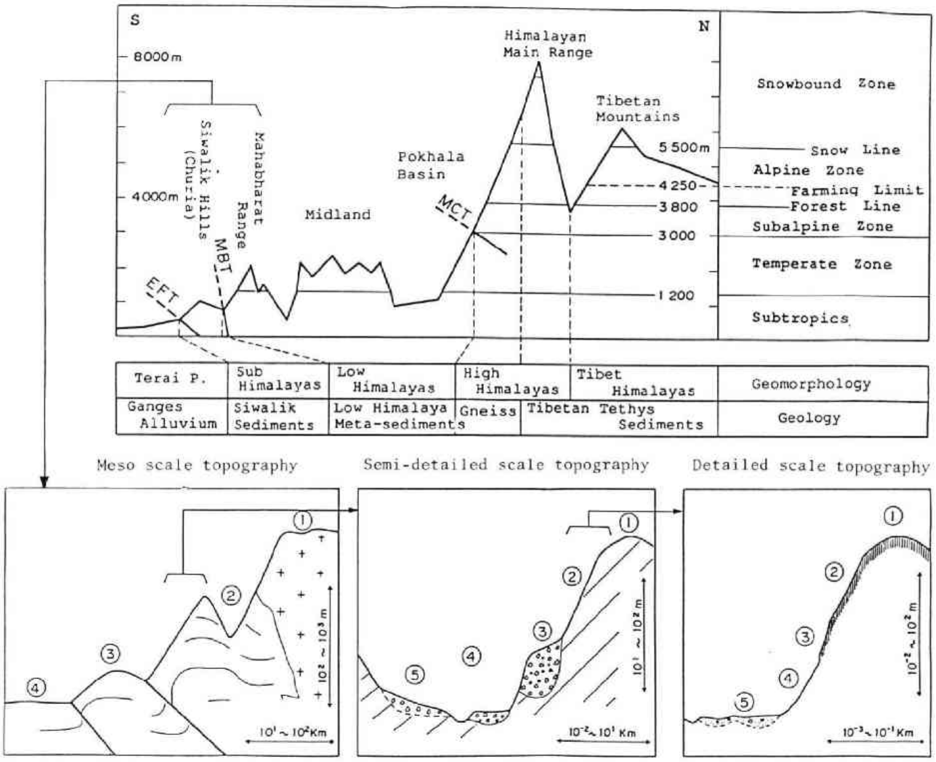
The Mahabharat Lekh and the Shiwarik Hills have similar features in macro-scale. Both of them are located in the southern part of the lower Himalayas and lie east to west with about 20 to 30 kilometers width and about 2,000 to 2,500 meters heights of ridges.

In the mesoscale topography, the Mahabharat Lekh is characterized by low relief surfaces and steep high-altitude slopes. Discriminative low relief surfaces develope around 2,200 to 2,500 meter a.s.l. such as Sign-Bangjan, Daman pass (Fig. 2-a), Chisapani, *etc*. No younger sediments have been found on the surfaces where deeply weathered granitic bedrock is exposed. The convex break of slopes is clearly distinguished between the low relief crest surfaces and valley-side steep slopes. Iwata (1988) estimates the rate of uplifting during these few million years as 1 to 2 milimeters annualy.

Individual ridge and ravine landforms are investigated in the semidetailed scale. This scale is almost equivalent to an area of local peoples's daily activity. The valley-side solpe in granitic areas is characterized with thin soil cover, ragged shape, and high relative elevation (500 to 1,000 meter usually). On the other hand, velley-side slope in the schistose area has ragged shape, slightly high relief, and fragile lithology. The valley-side slope is recognized as an assemblage of many slope segments in detail. These segments show spoon cut shape similar to shallow landslide topography and should be divided into the area of clear landslide assemblage and the area of wavy topography.

Some parts of ridges have distinctive smooth convex cross and longitudinal profiles which develope on several levels such as 1,000, 1,200, 1,600 and 1,900 meter a.s.l.

Four groups of river terraces develope along the upper reach of Rapti River, near Bhimphedi. The heighest and the second terraces are composed of thick (approximatery 50 to 100 meter) deposits consisting of subround to subangular boulder. They seem to be a result of huge and rapid sediment supply induced by, *e.g.*, debris avalanches and landslides. The third terrace is a strath of the second terrace. The fourth terrace seems to be alluvial one. Narrow flood plain developes along the river, particularly the reach lower than Bainsedobhan.



① Low-relief Surface
② Mahabharat range
③ Siwalik hills
④ Terai

① Hilltop slope
② Hillside slope
③ River terrace
④ River terrace-Bottom land
⑤ Foot slope

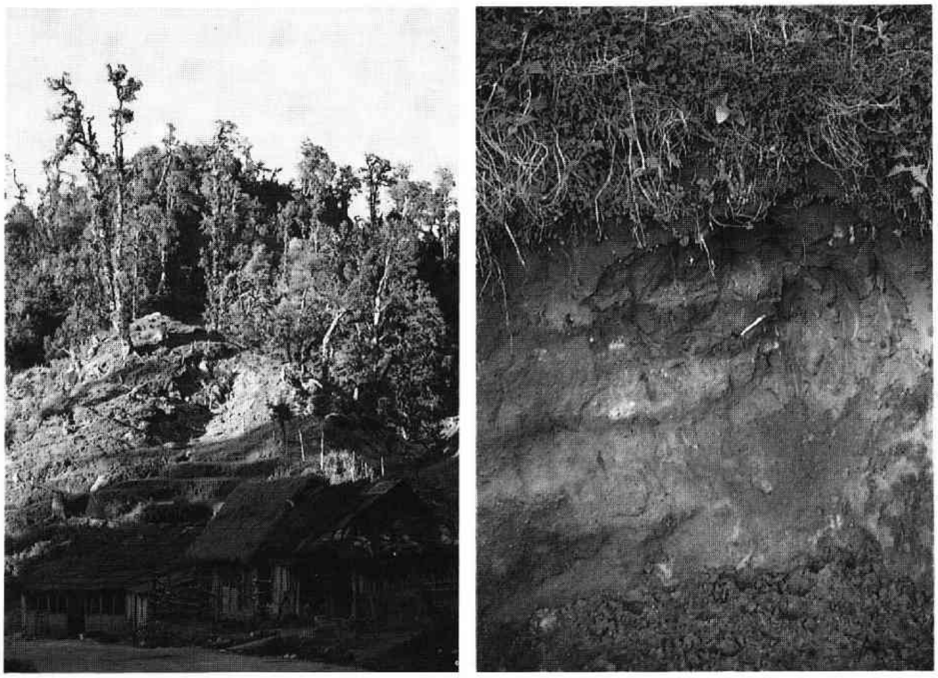
① Crest slope
② Upper sideslope
③ Lower sideslope
④ Surface landslide, Foot slope
⑤ Bootom land

Fig. 1 Multi-scale schematic cross profiles of Nepal and the study area. The cross profile of the Himalaya is adapted from Kizaki (1988).

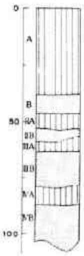
3 Geomorphic and Pedorologic features of detailed scale landform units

The detail research has been done in two sites, *i.e.* the right bank of the Kiseri River and the upper reach of the Jurikhet River, both of which are located along the upper Rapti River, the southern part of the Mahabharat Lekh. The geology of the study area mainly consists of granitic rocks in north eastern half, while the southern part consists of shist, slate, limestone, *etc.*

The detailed-scale landform of Jurikhet is classified as shown in Fig. 4. The area is characterized by steep valley-side slopes, narrow ridges and devastated channels. Remarkable block streams and tors develope on the granitic area. Lagre number of



a



Soil profile of crest slope (Damann) (Low relief surface).

A : Blackish brown humic loamy sand, slightly moist, massive, subangular pebble, many fine rots,

B : Brown Loamy sand, slightly moist, massive, many subangular pebble, roots,

IIA : Blackish brown humic loamy sand, moist, subangular blocky structure, many subangular pebble, roots

IIB : Brown Loamy sand, slightly moist, massive, many subangular pebble, roots,

IIIA : Dark brown humic loamy sand, moist, subangular blocky structure, many subangular pebble,

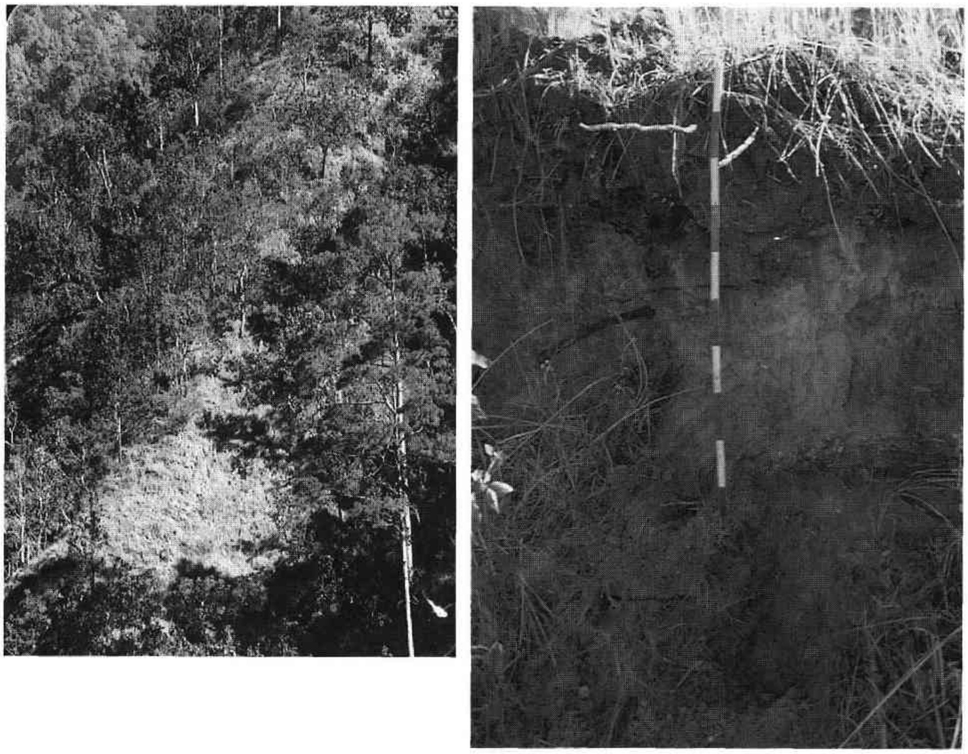
IIIB : Blackish brown loamy sand, slightly moist, massive, many subangular pebble,

IVA : Dark brown humic loamy sand, moist, subangular blocky structure, many subangular pebble,

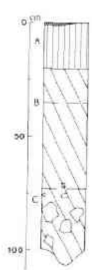
IVB : Dark brown loamy sand. slightly moist, massive, many subangluar pebble.

(This is a typical soil profile of the low relief surface. Mary horizon developed even on the crest slope)

Fig. 2a Typical landforms and soil profiles in and around the study area —— crest slope (Low relief surface at Damann pass) ——



b



Soil profile of crest slope (Jurikhet).

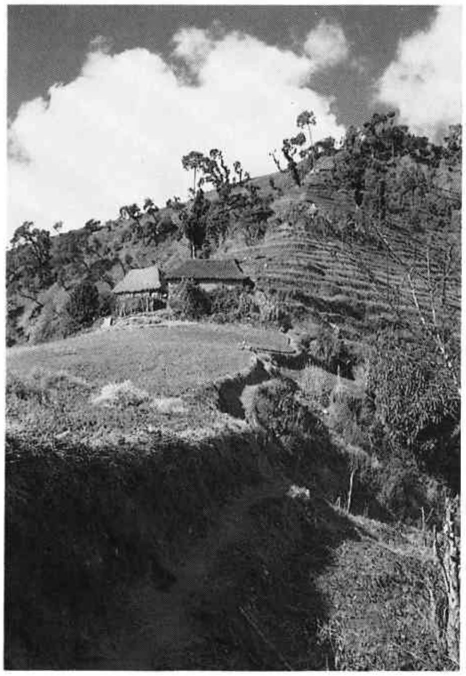
A : A1 Dark brown humic silt, slightly moist, massive, many fine roots,
A2 Brown humic silt, slightly moist, massive, few pebble, many fine roots,

B : B1 Light yellow brown silt, slighty dry, massive, slightly compact roots,
B2 Light yellow brown silt, slightly moist, massive, large root,

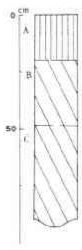
C : Silt loam, moist, many anguler gravel.

Topography : knife ridge, slope angle : 43
Bed rock : shist, Vegetation : pine forest.
(A1 horizon is disappear by surface denudation in frequently. Dry of B1 is noticeable.)

Fig. 2b Typical landforms and soil profiles in and around the study area —— crest slope (Knife ridge crest slope at Jurikhet) ——



c



Soil profile of crest slope (Jurikhet).

A: Blackish brown humic silt loam, moist, weak subangular blocky structure, subround pebble, many fine roots,

B: Dark brown silt loam, moist, weak subangular blocky structure, subround pebble, few fine roots,

C: Reddish brown silt loam, moist, subangular blocky structure, subangular to subround gravel and pebble.

Topography : crest gentle slope
Bed rock : shist, Vegetation : cultivated area
(C horizon seems to be red weathering crust. The thickness of the crust which amount more than few meters.)

Fig. 2c Typical landforms and soil profiles in and around the study area —— crest slope (Crest gentle slope at Jurikhet) ——

d

Soil prefile of upper sideslope (near Rani River).

B : Brown (reddish) silt, slightly moist, loose, weak crumb structure, angular gravel, many fine roots in the uppermost 20 cm. Basemant : shist, (Uper horizon is disturbed by cattle)

Fig. 2d Typical landforms and soil profiles in and around the study area —— Upper side slope (Slightly gentle slope at the Rani River) ——.

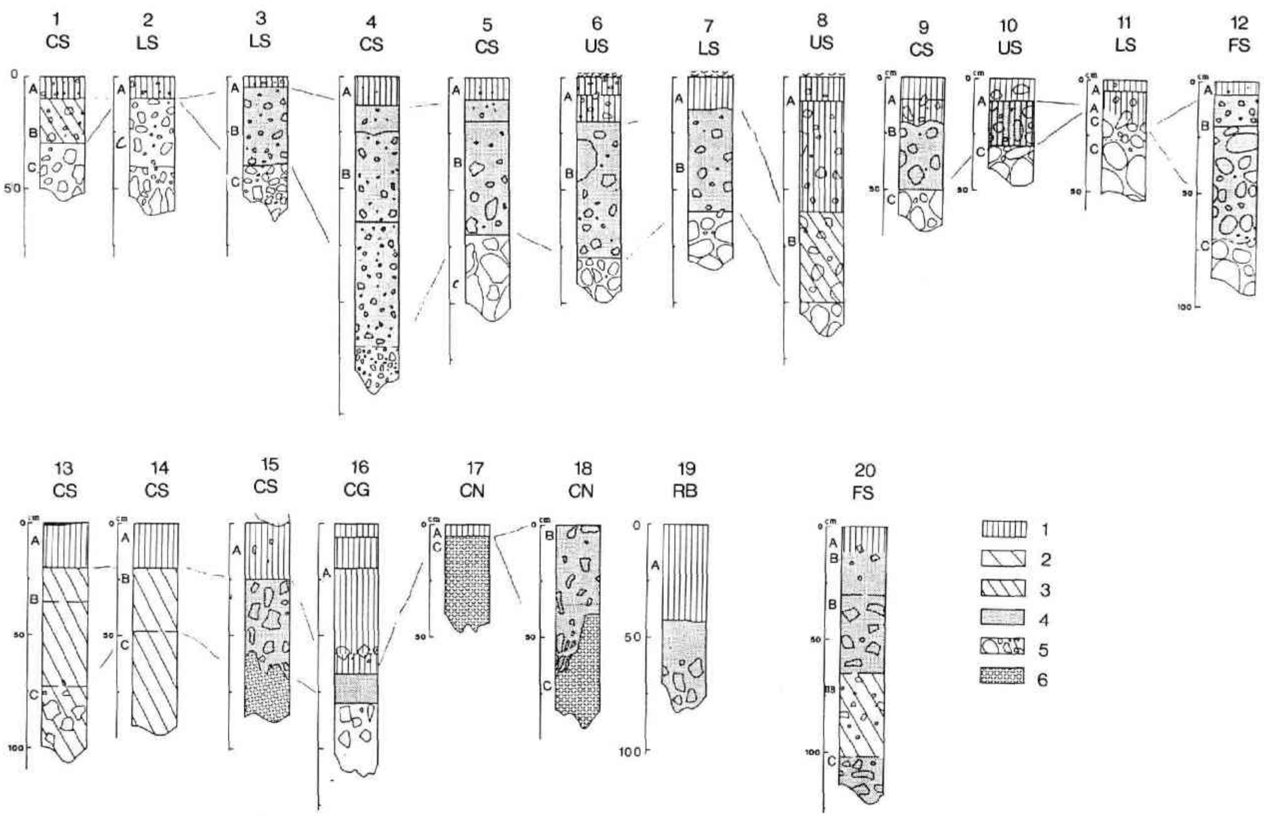


Fig. 3 Soil profiles in the study area.
No. 1 to 14 ; collected from Juriket area, No. 15 to 18 ; collected from Kiseri area. Other column : collected from between Bhinpedhi and Bhainsedoban.
1 : humus, 2 : clay, clay loam, 3 : silt, silt loam, loamy silt, 4 : sand, sandyloam, 5 : gravel, core stone, 6 : basements, CS : rest slope, CSG : crest gentle slope, US : upper side slope, LS : lower side slope, FS : foot slope, RB : river bank.

landslides and debris flow cones devolope on the schist zone. Several remarkable gorges and water falls develope on the boundary of the two rock groups.

Referring mainly to Tamura and Takeuchi (1980) and Tamura (1981), the slopes are categorized as the following landform units according to their shape, situation in their spatial arrangements, soil profile, *etc.* The each detailed scale landform unit is deliminated by breaks of slope whose sharpness is various. Several typical topography and soil profiles are show in Fig. 2-a to d. The landform units are categorized crest slope, crest gentle slope, upper side slope, lower side slope, head hollow, channelway, footslope, and bottomland. Several additional landform units such as terraces, landslides, distinctive cliff, and gorge are also illustrated in Fig. 4 and Fig. 5.

3.1. Crest slope:

The crest slopes usually appear on the top of cross profile as slightly convex segments and are partially broad and flat on main ridges. Shallow soil profile developes on strongly weathered bedrock on the crest slope (Figs. 3-1, 9, 13 to 15). The crest slope of the end of branch ridges is called "nose", where very shallow A/C or B/C soil profile, as a consequence of severe soil erosion, is observed (Fig. 3-17, 18). Broaded crest slopes partly permit the development of deeper and moderately moist soil profiles which have reddish brown humic B horizon on deep weathering crust of schist (Fig. 2-b, Fig. 3-4, 5). Shallow and weekly dry B and C horizons develope on the narrow ridges which have slightly high gradient (Fig. 2-c). Weak denudation mostly due to soil creep seems to prevail on crest slopes.

3.2. Crest gentle slope:

Somewhat gentle slope units exist adjacent to crest slopes or on the top of cross profiles. They are divided into slightly waving area and very smooth part. The unit developes widely in the Kiseri River. Soil of the unit is almost similar to that on the low relief surfaces. The lower and of these crest slopes are divided by distinctive convex break of slope from the other landform units such as side slopes. The break is named the erosion front I. The defintion of erosion front is given by Hatano (1974).

3.3. Side slope

Side slopes can be divided into upper and lower, and the boundary between them provides distinct convex break of slope or convex microsegment. The upper side slope is always gentler in perpendicular and smoother in contour line direction than lower one. Upper side slopes consist of straight or slightly convex segments which are mostly less than 30 to 35 degrees sloping and change upward to crest slope often without clear breaks. Solum on upper side slopes are not so shallow and their humic horizons are deeper than lower one and their equivalent crest slope (Fig. 2-d, Fig. 3-6).

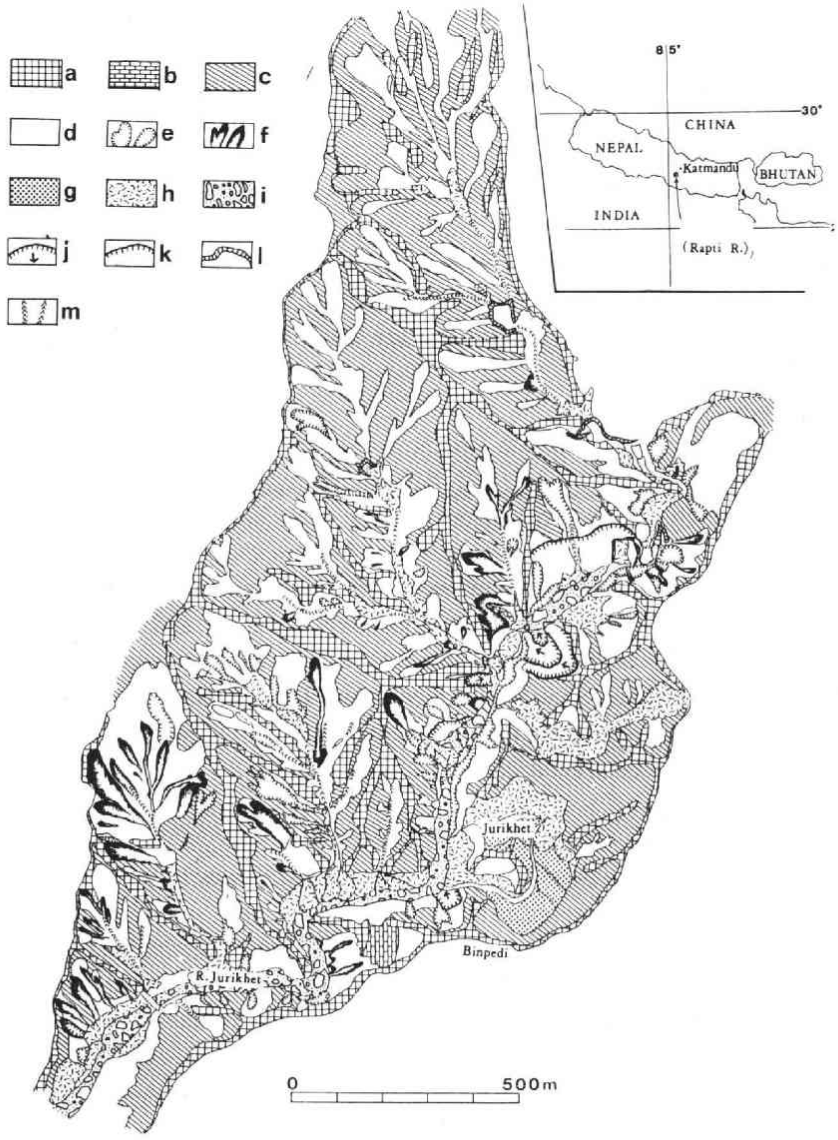


Fig. 4 Detailed-scale landform classification of the Jurikhet River area.
a : crest slope, b : head hollow, c : upper side slope, d : lower side slope, e : landslide in shape, f : fresh landslide, g : terraces, h : foot slope, debris flow, talus *etc.* i : bottom land, j : landslide in weathered rocks, k : major cliff, l : gorge, m : devarstated river.

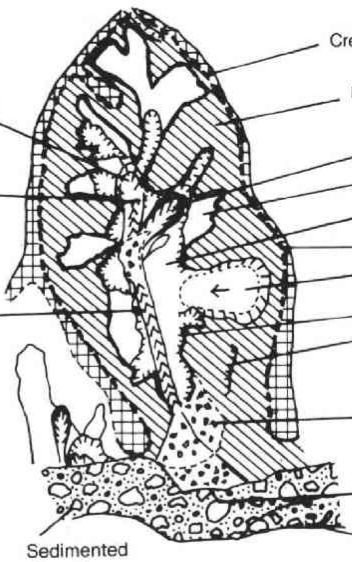


Fig. 4' Spatial arrangement of landform units, erosion front I and II.

But A1 horizon is absent sometimes. The extreamly steep upper side slopes have shallow soil profiles almost the same as lower one as shown in Fig. 3-10.

The lower side slopes consist of very steep concave segments reaching to 40 to 50 degrees which seem to be an assemblage of shallow landslides of various clearness. Actually, almost all the landslides occur in this landform unit. The solum on the lower side slopes are very shallow and loose, and the thickness of humic horizon is not uniform (Fig. 3-2, 3, 7, and 11). The lower side slopes seem to be very unstable. It consists of the following three types of shallow landslides: the first is fresh landslides characterized by distinctive shape, no vegetation cover, and exposure of deeply weathered schistose rocks. The second is clear in shape of slide but have vegetation cover and partly soil cover. The third is obscure in shape, and has slightly developed soil profile. The fresh landslides are distributed only in the area of schistose rocks (Figs. 4, 5).

There are distinctive convex breaks of slope as a boundary between the upper and the lower side slopes. The upper end of lower side slope means the margin of the area of frequent landslides. This boundary is named the erosion front II.

3.4. Head hollow:

Head hollows have a shape of typical concave profile in cross and in longitudinal

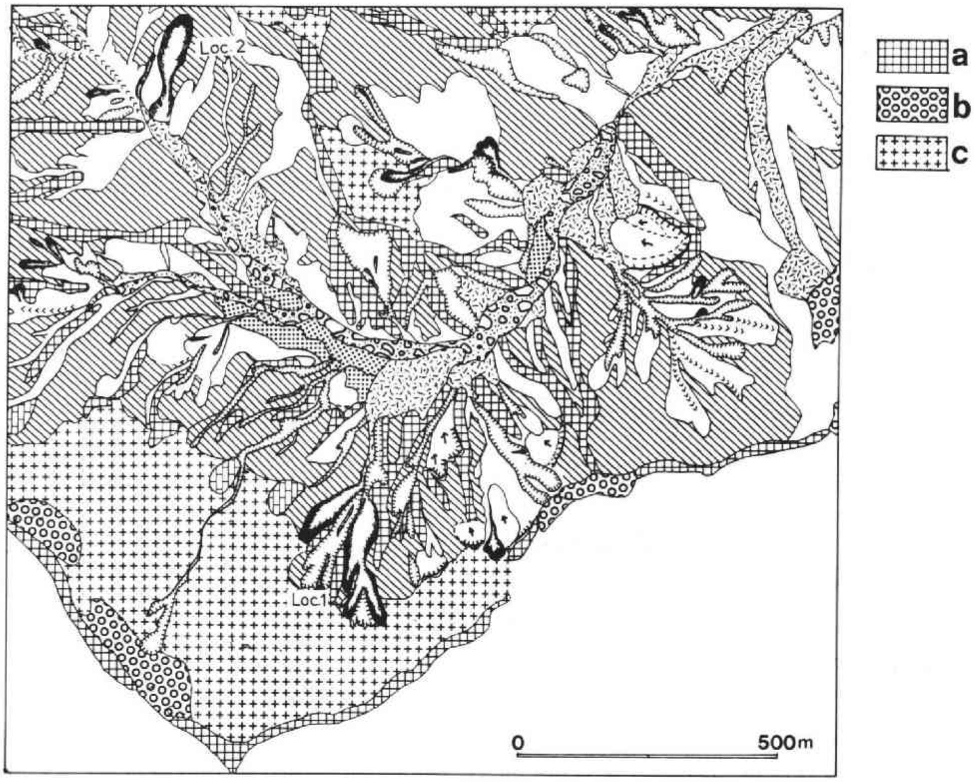


Fig. 5 Detailed-scale landform classification of the Kiseri River area.
a : crest slope, b : crest gentle slope (flat), c : crest gentle slope (smoothly waved), other simbols are same as in Fig. 4.

section. It means clear valley shape but none of channels are formed there. The typical head hollows are fewer in the study area than in the Shiwarik Hills. The head hollows develope at the headmost parts of streams and are surrounded by upper side slopes or adjacent to the lower end of crest gentle slope.

3.5. Channelway :

Channelways appears very abruptly at the lower end of head hollows as a size of several ten centimeter in width and one or two meters in depth. Near the upper end of a channelway, it is intermitted frequently. Lower side slopes are distributed along the both sides of a channelway.

3.6. Foot slope :

The lower end of lower side slope usually touches bottom of a channel, but

Table 1 Functioal characteristics of detailed scalelandform units and erosion fronts in the study area.

Detailed scale-landform units	Prevailing water movement	Predominant geomorphic processes	Morphogenetic tendencies	Soil	Slope instability
Crest slope	Vertical infilt-ration throughflow	Soil creep	Evolution of convex segment Evolution of convex segment	Residual soil Slightly dry	Slightly stable
Crest gentle slope	Through flow Stream flow	Soil creep* Sheet wash Rill erosion	Maintain of facet	Creep Residual soil Slightly dry	Slightly stable
Erosion front I		Soil creep* Land slide §	Baundary of Crest and valley side slope	Creep Colluvial	Unstable
Upper side-slope	Throughflow Overland flow Matrix flow	Soil creep* Lateral eluviation Sheet wash Landslide §	Maintenance of facet Outbreak of new valley-head	Creep Moist-slightry dry	Slightly unstable
Erosion front II	Piping Overland flow Through flow	Landslide*§ Sheet wash Creep	Break point of landslide	Creep Dry-moist	Very unstable
Lower side-slope	Throughflow Overland flow Piping	Landslide*§ Lateral eluviation Sheet wash Soil creep	Concave segment evolution Maintenance of facet	Creep Colluvial	Very unstable Concave steep slope Landslide in soil layer
Head hollow	Throughflow Overland flow	Soil creep* Lateral eluviation Sheet wash Landslide §	Subdueing of convex segment Formation and maitenance of micro-facets	Colluvial Creep Moist-Slightly wet	Unstable Temporal rill erosion
Channelway	Stream flow	Stream erosion	Down and undercutting	Colluvial Fluvial Sligtly wet-wet	Very unstable

* Principal process in each unit
§ Associate with slump, fall or flow

somtimes changes successively to gentle slope. These kinds of slightly gentle slope units are named "foot slope". It is formed as alluvial cone, debris cone, talus, *etc.* Some parts would be of erosional origin. The solum on foot slopes sometimes gravelly, loamy and cumulatively (Fig. 3-8, 12, 20).

3.7. Bottomland :

This landform units appear as a flat section at the lowest part of a cross section. It is formed by fluvial processes. In the case of study area, buried bottomlands are covered thinly by angular to subangular gravel and boulder. Thick angular gravel provided by landslides are accumulated and form debris flow robes along the second to third order channels.

4 Land evaluation and slope stability

I have clarified the characteristics and spatial arrangements of landform units, and have recognized natural environmental dynamics of landforms on which geomorphological, hydrological, pedorological processes have taken place. It is summarized in Table 1 which follows the form presented by Tamura (1981, 1987).

Most of rainfall infiltrates to soil and moves in the soil layer as thoroughflow on the crest slopes and crest gentle slope. The surface runoff will be of little amount in vegetated areas. Mass movement or soil transportation should be slow. Weak soil creep may occur in area of moist soil. It indicates relatively high stability of crest slope and crest gentle slope. However, soil profile charactersitics which have very this humified amorphous layer in spte of forest cover suggest weak surface denudation due to its topographc situation. Seldom landslides take place in these landform units such as Loc. 1 in Fig. 5. On lower side slopes, piping and saturation overland flow will appear frequently because of the concentration of soil water and convex break of profiles. Lower side slope is the area of surface landslides. This provides the most unstable landform unit in a cross profile. Almost all the surface landslides take place between the upper margin and lower end of this unit as shown in Figs. 4 and 5. The areal frequency of land-slides would be an indicator of debris yield. Head hollow is slightly stable in spite of its situation. Foot slope and channelway are very unstable because fluvial processes operate most activity in the units.

In this way, detailed and micro-scale landform classification makes it possible to estimate and evaluate surface stability of slopes, although further information is necessary, as Ives and Messeli (1988) suggest the importance of the exact field research and intensive data collection.

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