Need for soil study to determine degradation and landscape stability

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High altitudinal soils (Entisols and Ultisols) on different landscapes in Arunachal Pradesh were studied with respect to soil formation *vis-à-vis* soil erosion. The degradation of soils has been indicated using mainly the soil parameters with some site characteristics. The study indicates that the effect of soil development and its accumulation is obliterated by severe soil erosion, causing the formation of Entisols which are degraded under the present day situations. On the other hand, huge clay illuviation in the soils (Ultisols) indicates a relatively stable landscapes in the lower elevations. These Ultisols are also under rapid degradation process as indicated by the truncation of the upper layers. In the dominantly erosional landscape of the northeastern region of India, the series of ridges, valleys, terraces and scarps are the results of such differential erosions causing different degrees of degradation. Need for soil study to determine degradation and landscape stability is essential.

THE methods of soil degradation studies[1] indicate that areas mostly under forest vegetation should be considered as a stable terrain. Such inference on stability of landscapes, which has been further supported by others[2], only by examining the vegetation, appears to be misleading since degradation *vis-à-vis* stability of a landscape may not be easily comprehended in view of constant human intervention and neotectonics which are common in Arunachal Pradesh. The disturbances due to neotectonics[3] and the shifting cultivation, especially in the higher altitudes, make these landscapes more unstable because of inadequate time available for the development of soils. This suggests that in order to gain knowledge on the stability of the landscape *vis-à-vis* soil degradation, a systematic study on soils representing major landforms becomes imperative.

Materials and methods

Study area

The study area falls in the eastern part of the Sub-Himalayan belt with an elevation of less than 1700 m above msl of Arunachal Pradesh (Figure 1). The geology consists of sedimentary (sandstone) and metamorphic (state) rocks. The climate is humid subtropical characterized by high rainfall and high humidity. The annual rainfall varies from 3500 to 5500 mm with a maximum occurring during monsoon between May and August. The mean annual air temperature is 16.2°C. Most of the study area is under forest vegetation, viz. high-altitude banana (*Musa* sp.), bamboo (*Melocanna bamboosoides*) and sangrass (*Imperata cylindrica*), except a few patches which are cultivated for minor millets.

Three pedons were selected on the North-Eastern Himalayan region with a linear distance of 25–30 km (Figure 2) in the Papumpoma district of Arunachal Pradesh. These are Typic Udorthents (Pedons 1 and 2) and Typic Hapludult (Pedon 3). These pedons were identified at different elevations on the hill scarps interconnected with very narrow interhill basins. The high hills (sites of Pedons 1 and 2) are characterized by maximum dissection and very steep slopes (30–50%) with shallow soils (Typic Udorthents) upon highly weathered sandstones at an elevation of 500 and 450 m above msl, respectively (Figure 3). The moderate hill tops (site of Pedon 3) is at a relatively medium slope (15–30%) with very deep red soil (Typic Hapludult) situated on 200 m above msl. These Entisols and Ultisols are spatially associated as distinct entities with similar climatic conditions on the high altitudinal landscapes of Arunachal Pradesh which represents major landforms in the hilly terrain of northeastern region.

Methods

The morphological characteristics of the pedons as well as the general features of the pedon sites were studied as per procedures described in *Soil Survey Manual*[4]. The physical and chemical properties of the soils were analysed following standard methods[5].

Erosion is apparently severe in the sites 1 and 2 in the study area compared to site 3. Values of soil erodibility were calculated from particle size and organic matter data, along with soil structure and permeability characteristics, using the nomograph of Wischmeier *et al.*[6].

Results and discussion

Morphometric properties of soils

In site 1 stones of 7.5–25.0 cm size (or even bigger) cover 40–75% of the surface. Coarse gravels (2.5–7.5 cm), stones (7.5–25 cm) and boulders (> 25 cm) cover more than 50% volume of the horizons below 40 cm indicating that most of these horizons below 40 cm form AC horizons (Table 1). These stones are sandstone fragments derived from the bedrock. The other site characteristics, viz. very steep slopes (greater than 50%), severe to very severe erosion and very rapid run off indicate that these soils must have been deposited from still higher altitude and a little weathering of the bedrock might be relatively recent.

The site 2 resembles site 1 except that the sandstonic bedrock, relatively near the surface, is almost exposed to the weathering. The profile represents a side slope of the steep hills which are thickly covered by shrubs and mosses. Beneath it are highly weathered sandstones. The difference between C1 and C2 appears only as the degree of weathering and that C1 is slightly more reddish. The morphology of Pedons 1 and 2 (Figure 1) as well as depth distribution of sand and silt fractions on clay-free basis and the sand and silt ratios (Table 1) indicate lithological discontinuities[7]. A noticeable characteristic of Pedons 1 and 2 is a relatively higher content of sand (0.1–2 mm). It is obvious that at sites 1 and 2 the weathering of sandstone has given rise to high amount of sands in these two soils (Figure 4). The distribution of (clay-free) sand and silt fractions and their ratios (Table 1) point towards parent material uniformity in Pedon 3. Such homogeneity discounts clay enrichment of the B horizons caused by sedimentation. In view of the uniformity of the parent material, the clay distribution as a function of depth clearly indicates that these soils are fairly well developed. This is in accordance with the views of Barshad[8], who indicated that in a fairly well-developed soil, as a result of pedogenic processes, the clay content increases with depth to attain a maximum and then decreases until it remains constant or completely disappears. In Pedon 3, the clay content, however, decreases after attaining a maximum value of 475 g kg^{-1} at a depth of 115 cm.

Figure 1. A view of high altitudinal ranges in Arunachal Pradesh.

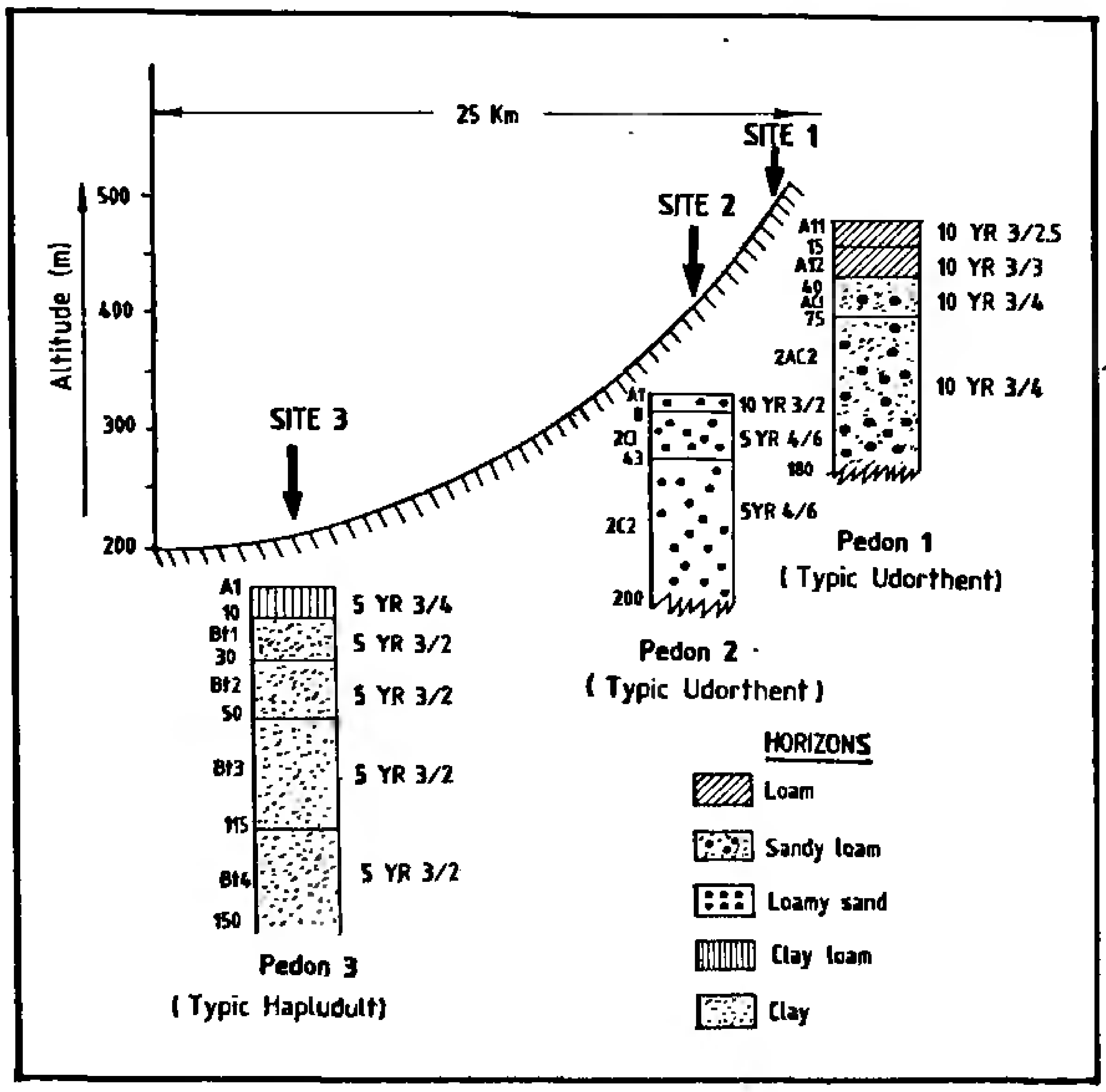

Figure 2. Soil site characteristics of high altitude terrain in Arunachal Pradesh (depth in cm).

Figure 3. Luxuriant vegetations of different forest species of high altitude banana and bamboo (SW of site 1 about 8 km NW of Doimukh, district Papumpoma, Arunachal Pradesh).

Physical and chemical properties of soils

Base leaching due to higher rainfall has more influence towards acidity in soils at site 3. On the contrary, lower pH in soils at sites 1 and 2 is probably due to presence of organic acids derived from vegetation either by leaf drip or litter decomposition (Table 2). The dithionite-extractable iron (Fed) values in Pedons 1 and 2 show little variation within the profiles and may indicate less weathering. It appears that higher Fed values are due to higher iron content of the bedrock and do not indicate a greater weathering intensity. This is amply proved by

Figure 4. Huge sandstonic rock mass in advanced stage of weathering causing continuous erosion near the river, Daimukh: the rounded pebbles carried by the river from the high hills of the Himalaya.

Figure 6. Still closer view showing destruction of natural vegetation due to severe soil degradation.

Figure 5. Degradation of soils and landscape: severe soil erosion affecting landscape stability (site 2, about 22 km SE of Kheel, district Papumpoma, Arunachal Pradesh).

Figure 7. High degree of erosion near the site 3 causing truncation of top soil layers (near Itanagar).

Table 1. Particle size and soil erodibility (*K*) data

Horizon	Depth (cm)	Volume basis: % gravel (> 2) (mm)	Fine earth basis ($g\,kg^{-1}$): Sand (0.1–2) (mm)	Fine earth basis: V.F. sand (0.1–0.05) (mm)	Fine earth basis: Silt (0.05–0.002) (mm)	Fine earth basis: Clay (< 0.002) (mm)	Organic matter ($g\,kg^{-1}$)	Structure	Permeability	*K*	Clay-free basis ($g\,kg^{-1}$): Sand (2–0.05) (mm)	Clay-free basis: Silt (0.05–0.002) (mm)	Sand/silt ratio
Pedon 1 (Typic Udorthent)													
A11	0–15	10–20	378	101	316	205	36	Blocky	Moderate	0.36	603	397	1.5
A12	15–40	20–30	426	84	295	205	29	Blocky	Moderate	0.39	634	366	1.7
AC1	40–75	40–60	478	84	258	180	14	Fine granular	Moderate to rapid	0.34	686	314	2.2
2AC2	75–180	50–70	546	78	206	170	12	Fine granular	Moderate to rapid	0.39	752	248	3.0
Pedon 2 (Typic Udorthent)													
A1	0–8	10–20	550	132	213	105	31	Fine granular	Moderate to rapid	0.36	721	279	2.6
2C1	8–43	30–50*	788	63	84	65	4	Very fine granular	Rapid	0.49	904	96	9.4
3C2	43–200	30–50*	732	65	128	75	3	Very fine granular	Rapid	0.54	851	149	5.7
Pedon 3 (Typic Hapludult)													
A1	0–10	3–5	344	52	279	325	36	Blocky	Slow to moderate	0.21	552	448	1.2
B11	10–30	3–5	285	43	262	410	31	Blocky	Slow	0.22	521	479	1.1
B12	30–50	5–8	254	36	250	460	14	Blocky	Slow	0.21	504	496	1.0
B13	50–115	5–8	239	31	255	475	10	Blocky	Slow	0.21	484	516	0.9
B14	115–150	5–10	298	30	252	450	8	Blocky	Slow	0.20	540	460	1.1

*Weathered sandstone boulders.

Table 2. Selected chemical data of the soils

Horizon	Depth (cm)	pH Water	pH NKCl	Extractable bases (cmol (+) kg^{-1}) Ca	Mg	Na	K	Total	CEC NH$_4$OAc (cmol (+) kg^{-1})	BS %	Fed %
Pedon 1 (Typic Udorthent)											
A11	0–15	5.7	4.4	3.4	3.2	0.4	0.3	1.3	9.8	79	0.8
A12	15–40	5.7	4.2	3.2	1.0	0.4	0.2	5.0	8.6	58	1.0
AC1	40–75	5.6	4.1	2.4	1.0	0.3	0.2	3.9	7.6	51	1.2
2AC2	75–180	5.4	4.0	1.8	0.6	0.3	0.2	2.9	7.0	41	1.2
Pedon 2 (Typic Udorthent)											
A1	0–8	5.3	4.5	4.0	1.2	0.4	0.2	5.8	8.8	66	0.6
2C1	8–43	5.5	4.2	3.2	0.8	0.3	0.1	4.4	6.0	74	1.1
2C2	43–200	5.1	4.0	3.6	1.0	0.4	0.1	6.1	8.2	74	0.3
Pedon 3 (Typic Hapludult)											
A1	0–10	5.6	4.4	2.6	1.0	0.3	0.6	4.5	9.6	47	1.0
B21t	10–30	5.3	4.0	1.2	0.4	0.4	0.2	2.2	9.4	23	1.7
B22t	30–50	5.3	4.0	0.8	0.4	0.4	0.3	1.8	10.0	18	1.9
B23t	50–115	5.3	3.9	0.8	0.2	0.3	0.2	1.5	12.2	12	1.7

low Fed values but highly weathered CI horizon of Pedon 2 (Table 2). On the other hand, the translocation of iron as indicated by dithionite-extractable iron (Fed) values in Pedon 3 shows evidence of clay illuviation.

Development of soils vis-à-vis erosion

The climate in the study area is sufficiently warm (during summer) and moist (during rainy season) and the parent materials are not resistant to weathering. Therefore, the reason for the apparent limitation in terms of horizon differentiation in Pedons 1 and 2, is probably due to the fact that these soils are developed on unstable slopes, making more water available for surface runoff rather than for infiltration and thus causing more soil loss through water erosion. The effect of soil development and its accumulation is thus obliterated by the erosion and, therefore, both these sites are presently under degradation (Figures 5 and 6).

The soil erosion causing degradation has been reported by several authors from this part of the Himalaya. As a whole, from the Indian Himalaya, about 28.2 tons/ha/yr soils are eroded[10], while from the Lesser Himalaya and Siwalik watershed 80–156 tons/ha/yr soils are removed[11]; and in the submontane Punjab of northwest India soil loss of 20 tons/ha/yr has been reported[12]. Soil erosion from hill slopes (60–70%) under first year of jhum, second year of jhum, abandoned jhum (first year fallow), natural bamboo and mixed forest areas of Meghalaya was estimated at 144.6, 170.2, 30.2, 8.2 and 18.8 tons/ha/yr, respectively[13]. A study on the soil degradation of Arunachal Pradesh (personal communication) indicates more than 40 tons/ha/yr erosion in the areas with steep to very steep slopes (sites 1 and 2) and 20–40 tons/ha/yr with moderate slopes (site 3). While these general observations are of interest, detailed inter-regional comparisons are unadvisable on the basis of these limited data.

The similarity of soil chemical properties of Pedons 1 and 2 (Table 2) as well as the climate indicates that the rocks at site 2 are equally capable of producing soils with similar clay content as observed in Pedon 1. However, the clay content is relatively less and lithological discontinuities are more in Pedon 2 than in Pedon 1 (Figure 2 and Table 1). This indicates more soil loss through water erosion at site 2 which is more steeply sloping than site 1. It thus shows a differential rate of soil erosion leading to a different degree of landscape degradation in the high altitudinal terrain of Arunachal Pradesh even with similar environment. This is also in conformity with the soil erodibility values (K) which are higher in Pedon 2 (0.36–0.54) than in Pedon 1 (0.36–0.39) (Table 2). In the dominantly erosional landscape of the northeastern region of India, the series of ridges, valleys, terraces and scraps[3] are the result of such differential erosions and their subsequent depositions.

More than 20% clay increase in the subsurface horizon over the surface qualify for an argillic horizon in Pedon 3 (ref. 14). Due to probable truncation of the upper layers of these Ultisols (Figure 7), the total clay content presently shows a sharp decline in the A horizon (Table 1). Judging by the huge clay illuviation in these soils, it appears that the landscapes at lower elevations (site 3) might have been more stable in the past. With time, modern civilization in the form of rapid urbanization has brought instability in these landforms resulting in such truncated soils due to soil loss through water erosion, which is also indicated by the soil erodibility values as shown in Table 1 (ref. 6).

Conclusions

Information on soil development, erosion and deposition and the balance of these three processes indicates the extent of soil formation *vis-à-vis* soil loss in a landscape. Basic data on soils and the site characteristics are, therefore, important for determining degree of soil erosion to assess degradation of soils as well as the landscapes. Although all the sites described in our study are continuously eroded, the site 3 with soils containing huge clay is at a less degree of degradation than the soils at sites 1 and 2. While the soil degradation due to shifting cultivation and other human intervention can be controlled, the conservation of landscape degradation due to neotectonics is yet to be found out.

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Detection and identification of seismic signals using artificial neural networks

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Artificial neural networks (ANNs) are emerging as potential tools for the detection and identification of seismic signals owing to the fact that they can be adapted to fit more complex decision surfaces compared with the conventional techniques. This paper deals with the development of two ANNs, one for the purpose of on-line detection of seismic signals and the other for the identification of the signals. It has been demonstrated that these ANNs, trained with various parameters derived from the digital data as obtained from the Gauribidanur seismic array, India, have excellent capabilities to detect and identify weak seismic signals.

DETECTION and identification of seismic signals, having body wave magnitudes (mb) four or more, at teleseismic distances seem feasible with the presently available instruments and data analysis methods. However, identification of small magnitude events which could be recorded only at regional distances (< 2000 km) requires significant efforts to devise techniques for detecting, analysing and interpreting such regional data. With ever-increasing inflow rate of digital data, on-line processing of seismic data has become a necessity. Modern high speed digital computers have over the years made it possible for the users to implement various sophisticated processing algorithms to extract meaningful information from raw data. Presently, extensive research efforts are directed towards the designing of artificial neural networks (ANNs) which are conceived as promising solutions to various complex artificial intelligence problems like pattern and speech recognition[1–4]. ANNs are also emerging as potential tools in the field of seismic signal detection and identification.

The present paper deals with the development of two ANNs for the purpose of signal detection and identifi-