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LOCAL KNOWLEDGE AND CONVENTIONAL SOIL SCIENCE APPROACHES TO EROSIONAL PROCESSES IN THE SHIVALIK HIMALAYA

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ABSTRACT Local ('indigenous') knowledge and conventional ('modern') science are both limited in their abilities to mitigate soil erosion hazard in the Himalaya. While each system's terminology for erosion results from distinct perceptions of the environment, each responds differently to hazard. Local knowledge primarily responds over the long term and over areas beyond the actual site of soil loss. In a complementary manner, conventional science emphasizes erosion control in the short term and on-site. A case study from the Shivalik Hills in India is used to demonstrate these complementarities. The local dialect contains a detailed lexicon for landforms, soils, hydrology, and erosion, suggesting that environmental processes are understood. In the local approach to erosion, land use is altered to maintain biomass productivity. Thus, tenure and management issues are important. Conventional science seeks to reduce downstream sedimentation by controlling erosion through structural and vegetative techniques which are implemented for short-term results and are largely confined to the site of soil loss. In the Shivaliks, local approaches (intensification of agriculture through irrigation on stable lands and grazing control on erodible lands) are complemented by conventional techniques (sediment traps, earthen dams and planting trees and grasses). In the process, productivity has increased and sedimentation has been reduced.

RÉSUMÉ *Connaissances locales et méthodes classiques de la science des sols vis-à-vis des processus d'érosion dans les Siwalik.* Les connaissances locales et les méthodes classiques de la science des sols sont toutes deux limitées en ce qui concerne la maîtrise de l'érosion du sol dans l'Himalaya. Bien que la terminologie utilisée par chaque approche découle d'une perception particulière de l'environnement, la réponse aux risques d'érosion est différente pour chacune d'entre elles. Les connaissances locales s'addressent plus particulièrement aux risques à long terme pour des zones s'étendant au-delà du site d'érosion particulier. Par contre, les méthodes classiques de la science des sols mettent plutôt l'accent sur la maîtrise à court terme de l'érosion pour un site particulier. Une étude de cas effectuée dans les Siwalik, chaînes préhimalayennes de l'Inde, est utilisée pour illustrer la complémentarité de ces deux approches. Le dialecte local contient un vocabulaire étendu se rapportant aux formes de terres, aux sols, à l'hydrologie et à l'érosion, indiquant une bonne compréhension des processus environnementaux. L'approche locale modifie le mode d'utilisation des terres en vue de maintenir la productivité de la biomasse et donc les questions de régime foncier et de gestion sont importantes. Par contre, l'approche scientifique classique cherche à réduire la sédimentation en aval en maîtrisant l'érosion à l'aide de techniques structurelles et végétatives visant à des résultats à court terme en grande partie localisés au site d'erosion. Dans les Siwalik, les approches locales (intensification de l'agriculture par l'irrigation des terres stables et contrôle du pâturage sur les terres sujettes à l'érosion) sont complétées par les approches scientifiques classiques (pièges à sédiments, barrages en terre et plantation d'arbres et d'herbes). Le résultat en est une augmentation de la productivité et une réduction de la sédimentation.

ZUSAMMENFASSUNG *Erosionsvorgänge im Shivalik-Himalaya aus der Sicht von lokaler Erfahrung und konventioneller Bodenkunde.* Lokale ("einheimische") Erfahrung und konventionelle ("moderne") Wissenschaft sind in ihren Möglichkeiten, Bodenerosionsgefahren im Himalaya zu bannen, begrenzt. Die Terminologie beider Methoden für Erosionsvorgänge ergibt sich aus unterschiedlichen Blickpunkten auf die Umwelt, und jede reagiert anders auf Gefahren. Lokales Erfahrungsgut ist in erster Linie auf langfristige Lösungen ausgerichtet, und auf solche, die über die eigentliche Stelle des Bodenverlustes hinausgehen. Die herkömmliche Wissenschaft konzentriert sich auf direkte Erosionskontrolle vor Ort. Eine Fallstudie aus den Shivalik Bergen Indiens zeigt, wie sich beide Methoden ergänzen. Aus dem detaillierten Wortschatz im lokalen Dialekt für Landformen, Böden, Wasserkunde und Erosion, kann geschlossen werden, daß Umweltvorgängen viel Beachtung geschenkt wird. Bei einheimischer Erosionskontrolle wird in erster Linie die Landnutzung so verändert, daß die Produktion der Biomasse aufrechterhalten bleibt. Dadurch werden Fragen des Grundrechts und des Managements wichtig. Die konventionelle Wissenschaft dagegen versucht, die Sedimentation flußabwärts dadurch zu reduzieren, daß Erosionsvorgange durch strukturelle oder vegetative Techniken eingedämmt werden. Diese Eingriffe werden als Sofortlösung ausgeführt und beschränken sich hauptsächlich auf die unmittelbaren Stellen des Bodenverlustes. In den Shivalik Bergen ergänzen sich lokale Methoden (eine Intensivierung der Landwirtschaft durch Bewässerung stabiler Landflächen und kontrolliertes Weiden auf erosionsgefährdetem Land) mit konventionellen Verfahren (Sediment-Auffangvorrichtungen, Erddämmen und durch Anbau von Bäumen und Gräsern). Als Folge dieser Maßnahmen ist die Produktivität gestiegen und die Sedimentation zurückgegangen.

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COMPLEMENTARY APPROACHES TO EROSION

Prior to setting forth the theory that erosion hazard in the Himalaya is most effectively managed through a judicious combination of land users' and scientists' knowledge, a brief note on the terminology used in this paper is in order. Because all knowledge systems today adapt diverse sources of knowledge, the term 'indigenous' is misleading; instead, we will use 'local' knowledge. Similarly, because the conservation techniques of 'modern' soil science have not changed appreciably in decades, we will use the term 'conventional' science, which conveys that accepted procedures are followed for the identification of problems and application of solutions. Finally, by 'mitigation of erosion hazard' we refer to actions that diminish the negative effects of erosion.

Under present conditions in the Himalaya, the responses to erosion posed by both local knowledge and conventional science have limited effectiveness. As we will show, the local approach of changing land use is constrained by limits to the expansion of cultivable land and by the production needs of a growing population. Conventional science's emphasis on the control of erosion using structural and vegetative techniques is unable to adequately respond to major soil and rock movements linked to slope instability and tectonic activity. In order to more effectively mitigate erosion hazard in the region, there is a need to develop and implement additional techniques along the spectrum extending from land use to erosion control.

We therefore introduce the theory which holds that local knowledge and conventional science approaches to erosion in the Himalaya are complementary, considering the timeframe and spatial scale of the responses posed by each system. Fundamental differences in perceptions of the environment by local inhabitants and scientists are taken into account. These differences result in distinct types of terminology for erosional and hydrological processes: local knowledge is specific while conventional science is generalized. The specific nature of local knowledge dictates a unique response to each erosion event; this takes time and involves land-use changes beyond the particular landform under hazard. Conventional science primarily formulates general responses to erosion events; these may be implemented more rapidly and are usually limited to the actual hazard site.

In assessing responses to erosion, the rapidity and reversibility of soil loss are critical issues. We maintain that erosion occurs on three discernible timeframes: the agricultural; the human/ecological; and the geological. In the agricultural timeframe, erosion occurs over a span of seasons or years. An example is sheet erosion, which may prompt Himalayan farmers to alter cropping. Erosion in the agricultural timeframe is reversible. The human/ecological timeframe is determined in decades. For instance, gully erosion, while occasionally rapid, usually takes place over one or more human generations, with attendant changes in the species mix of plant communities. In this way, the human and ecological timeframes are generally compatible. Here, irreversible erosion may occur. The geological timeframe is measured in centuries, millennia, or longer. Catastrophic soil and rock movement events, which occur virtually instantaneously, are caused by geomorphic forces. Reversibility is not an issue.

The rapidity and reversibility factors indicate that conventional science is best suited to manage erosion in the agricultural timeframe. Rather simple techniques can rapidly be adopted to intervene and control (reverse) sheet erosion. The land-use approach of local knowledge systems is most appropriate to mitigate the effects of erosion in the human/ecological timeframe. Thus, conventional and local approaches to erosion are complementary; each prioritizes responses to erosion over a different timeframe.

The theory is explored with reference to erosion, hydrology, land use, and control measures in the village of Dhamala in the Shivalik Hills in the state of Haryana, India. From 1976 to 1990, when a combined land-use and erosion control approach was being implemented, the biomass productivities of agriculture, timber, and fodder grass increased by 120%, 50%, and 600% respectively (Scott, 1991). Multiple year average rates of sedimentation downstream were reduced by 92% from the 1959–64 period, when conventional erosion control techniques were implemented, to the 1979–82 period, when the combined approach was followed (Bansal and Mishra, 1982). It is demonstrated that land-use changes, in the form of grazing control on erodible forest land combined with localized intensification of agriculture through irrigation, are complemented by structural and vegetative interventions to control erosion and reduce sedimentation. Structural interventions include contour bunds, gully plugs, sediment traps, and water-harvesting dams; the planting of trees and grasses is a vegetative intervention.

THE LOCAL KNOWLEDGE APPROACH

Land-use planning has characterized the dominant historical approach to erosion in the Himalayan region. In view of the inevitability of erosion, inhabitants changed land use as the most effective tool in mitigating hazard (Zurick, 1990). When erosion resulted in declines in productivity (or total loss of the land parcel), land was used less intensively as the first option. Later, land use was completely altered if necessary and the intensive use of land was spatially separated from the hazard site. For example, a farmer who observed soil loss from dry terraced agricultural holdings might prolong the fallow and reduce tillage, and subsequently convert the land to pasture if necessary. Invariably, another physical location would be found for the intensive use. Wet terraced rice cultivation that led to slope instability would be moved to another more stable site (Datt, 1991).

Techniques for erosion control were certainly employed in traditional agriculture; for example, terracing has been mentioned. However, labor investments in the construction of erosion control structures were often lost during catastrophic mass wasting events. The prevailing attitude in the Himalaya is one of resignation to major soil loss events. While this may be partially based on religious belief, it also suggests to us that Himalayan inhabitants are aware that the magnitude of geophysical erosion may defy human control.

The linkages between erosion, land capability, and agricultural productivity are well understood by local land users in the region. For example, appropriate uses are determined for particular features of the landscape in the Indian Himalaya, depending on their erodibility and hence their capability to support irrigation, rainfed agriculture, or pasture (Datt, 1991). In the Middle Hills of Nepal, soil color, texture, and erosion hazard are held to be determinants of agricultural productivity (Gurung, 1989; Müller-Böker, 1991). In some cases, natural and human-induced soil movement is used to enhance land capability (Gurung, 1989). In parts of the Shivalik Hills, land capability and erodibility determinations continue to be based on revenue (linked to productivity) categories dating back to the Mughal period (Scott, 1991). In this system, productivity classifications for both agricultural and forest lands include: 1) *Abal*–the most productive; 2) *Dom*–slightly degraded but with considerable potential; 3) *Som*–degraded land, once productive; and 4) *Chikni*–no productive potential. *Chikni* (clayey) soils in the Shivaliks occur as exposed, highly erodible cliff faces.

Historically, greater constraints to the expansion of cultivable land were imposed by the shortage of labor than of land (Regmi, 1976). Although resources in the Himalaya were never adequate to entirely meet the subsistence needs of inhabitants, necessitating trade and migration (Allan, 1991), recent demographic changes have reversed the labor-to-land ratio in the principal zones of settlement in the region. Current demographic trends are consequently forcing inhabitants to modify traditional approaches to erosion (Exo, 1990).

THE CONVENTIONAL SCIENCE APPROACH

Conventional scientific understanding of erosional processes and particularly techniques for soil conservation have been strongly influenced by early experiences in the United States in the 1900s. The building of structures for on-site erosion control of agricultural fields was the primary activity of the Soil Conservation Service during the Dust Bowl of the 1930s. Subsequently, reducing sediment transport became an important objective to support river valley projects. For example, notable successes in the reduction of sedimentation were achieved in the Tennessee Valley Authority projects. More recently, emphasis has been placed on crop residue management to minimize the detachment of soil particles by raindrop impact. Maintaining upland agricultural productivity has received somewhat lower priority.

Given the prolonged dry season in much of the Himalaya as well as grazing and fuel needs, vegetative techniques to reduce erosion have not been given emphasis by the practitioner of conventional science. Greater emphasis is placed on control of sediment already generated than on source reduction through alteration of land use. It can only be conjectured here whether this emphasis can be best attributed to disciplinary specialization, to the fact that the motivation for erosion control in upland regions has frequently been to reduce sedimentation downstream, or to the allure of technologies for erosion control developed in Northern countries where reductions in the rate of sedimentation have, in fact, been substantial. Conventional science in the Himalaya has prioritized measures for river bank stabilization, gully training, and techniques to support road construction that rely on gabion walls, check structures, drainage diversions, and so on. All of these techniques are implemented at the actual hazard site, i.e., at the eroding river bank, gully, or unstable slope.

More recently, scientists have studied erosion in the Himalaya from a geomorphic perspective. Uplift and denudation result from orogenesis and seismic activity (Bansal and Mishra, 1982; Molnar, 1986; Ives and Messerli, 1989). In tectonically active regions such as the Himalaya, rates of uplift may exceed rates of denudation, despite the latter being several millimeters annually. Earthquakes resulting from the subduction of the Indian plate may trigger massive soil and rock movement, as witnessed in the October 1991 event in the Garhwal Himalaya. It seems certain that major earth movements, including landslides and debris flows, account for a high proportion of river-borne sediments, both suspended and in bedload (Carson, 1985; Hamilton, 1987). Hamilton (1987) contends that farming and forestry practices, in comparison with natural downslope processes, have negligible short-term impact on the rates of sediment delivered in the downstream reaches of large Himalayan rivers.

Current understanding of erosional processes in the Himalaya thus suggests that control or even appreciable reduction of sedimentation is not a feasible objective in the short term and over widespread areas. The conventional approach to erosion, which is based on a particular set of experiences not specific to the region, is constrained by geomorphic processes in the Himalaya.

KNOWLEDGE SYSTEMS

We have attempted to show that local knowledge and conventional science are limited in their individual abilities to manage erosion in the Himalaya. Before establishing the complementarity of the two systems, we must account for the very different perceptions each has of the environment. Humans' views about the environment are created and transmitted in numerous ways. Perceptions of the relationship between inhabitants and their habitat are primarily extensions of culture and cosmology (Slikkerveer, 1989) and may be reflected in language. Thus, the extent of a society's vocabulary for environmental processes is one indicator of the importance such processes have in that society.

Detailed descriptive systems, however, are founded on more than just utilitarian considerations. Non-utilitarian value may be expressed in religiously-toned language (Burger, 1990; Olson, 1990; Müller-Böker, 1991). Myths, for example, are often repositories of environmental knowledge (Scott, 1989). In actuality, local knowledge systems are based on a combination of practical experience and traditional wisdom. As Hewitt (1988: 14) puts it, "there is a vast range of organized, determinate, intentional and repetitive activities in every society that lie between the extremes of biophysical reflex and mere whim."

Local knowledge of the environment, which links land use with hazards, is rooted in intimate experience of specific processes. For this reason, soil erosion classifications among Himalayan societies are very precise (see also Gurung, 1989; Scott, 1990; Datt, 1991). Particular techniques for erosion mitigation in the Himalaya are developed and refined through trial and error (Messerschmidt, 1990). Thus, the generation of local knowledge is continuous.

Conventional science establishes general principles. Conservation-oriented soil science taxonomies for erosion (e.g., SCSA, 1977; FAO, 1979) describe complex processes using compound descriptors, for example, 'gullyhead,' 'bank undercutting,' and so on. It is not surprising that local and conventional systems use different terminology; linguistic differences are clearly operative. Nevertheless, there persists the more fundamental distinction between general and specific (or particularistic) knowledge systems.

Applied engineering science seeks to manage erosion through a series of interventions aimed at controlling erosion. The techniques employed toward this end have tended to be structural, built of stone and soil, although vegetative techniques are increasingly recognized for their effectiveness. In many cases, complete elimination or at least significant reduction of erosion is the justification for the level of effort required to implement the technique.

Significant potential exists in bringing together local and conventional approaches to land use and erosion control (see also Millington, 1984; Moench and Bandyopadhayay, 1985; Browman, 1987; Chambers *et. al.*, 1990; Hecht, 1990; ILEIA, 1990; Messerschmidt, 1990). The adaptive, innovative nature of local knowledge systems (McCorkle, 1989; Richards, 1989; Messerschmidt, 1990) indicates that borrowing from conventional science does not necessarily compromise their effectiveness.

It has been suggested by Thrupp (1989: 19), however, that attempts to 'scientize' local knowledge systems may result in their marginalization and loss of value. In the process of bringing different systems together, land-use decision-making may shift away from local inhabitants toward national level planners. We hold that the application of more than one knowledge system to the process of soil erosion will most effectively mitigate hazards if decisions are taken locally. Such a process demands that techniques be practical from the perspective of collaborative implementation and local management (Dani and Campbell, 1986). The case study in the Shivalik Hills demonstrates that combining local and conventional approaches to erosion is feasible if it takes advantage of existing complementarities.

A CASE STUDY FROM THE SHIVALIK HIMALAYA

A *dun* valley (intermontane, broad valley parallel to the thrust plane) along the southwest flank of the Himalaya is the site of the case study. Field study was conducted in 1990 in the three adjoining villages of Lohgarh, Dhamala, and Sukhomajri, which will collectively be referred to as Dhamala. Sukhomajri is well known for the successful watershed conservation program undertaken to reduce sedimentation of Sukhna Lake. Dhamala (Figure 1) faces the first range of the middle Himalayan hills of Kasauli, Himachal Pradesh. Elevations in the study area range from 485 to 600 m.

Climatic data relevant to erosion are taken from a weather station located 10 km southwest of the study area in the Shivalik Hills at an elevation of 346 m. Rainfall intensity data are available from 1962 to 1986, during which period the maximum 5-minute intensity recorded was 197.1 mm/hr (CSWCRTI, 1989). The erosivity of such intensities on erodible Shivalik soils is high. Additionally, high intensities occur when the soil is saturated and the free water surface is close to the ground level, further increasing gully erosion. The Shivalik relief to the southwest facing the Punjab plains is gentle; to the northeast, considerably more abrupt; here slopes in excess of 100% are widespread.

Data for a detailed soil-type classification are not available. However, it is known that the Shivaliks are composed entirely of alluvial sediments. The Lower Shivaliks, dominated by unconsolidated sand and gravel, often interlaid with clay horizons, were deposited some 10–15 million years ago, only to be uplifted again.

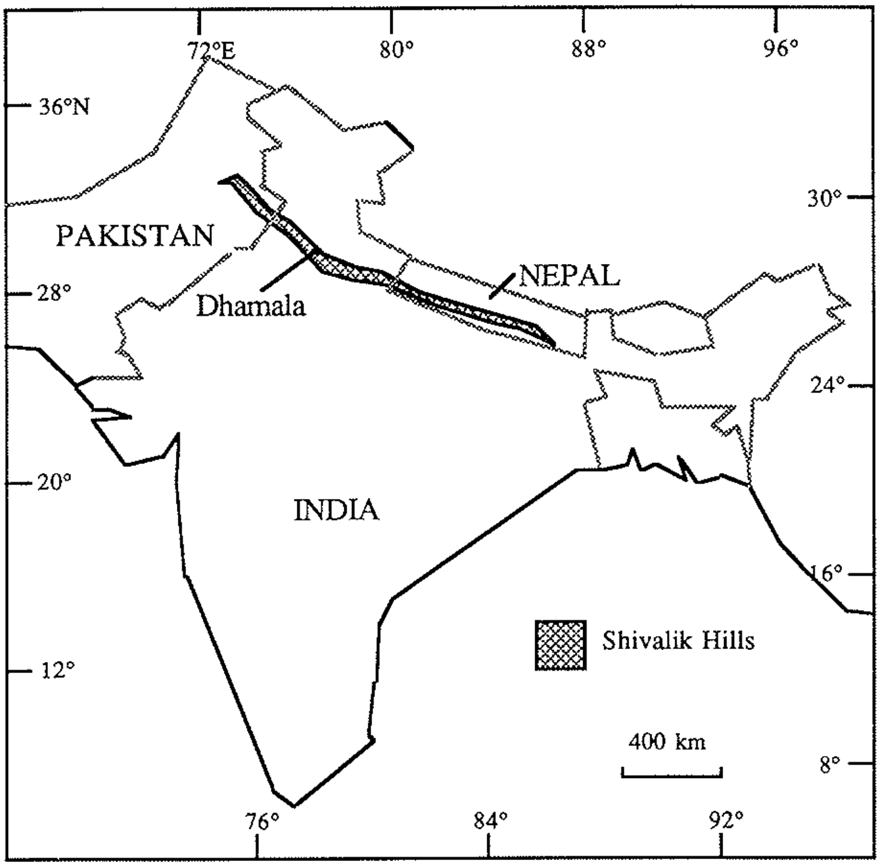

Figure 1. The field study site, Dhamala village, is located in the Shivalik Hills in India.

Likewise, the Upper Shivaliks, made up of conglomerates, were deposited only a few million years ago (Molnar, 1986). Soils in the Shivaliks are low in organic matter, due in part to minimal leaf litter, as well as to rapid oxidation in high daytime temperatures. Generally alkaline, soil pH values have been measured at 9.4 (Grewal *et. al.*, 1987). The predominant silt loam and silty clay loam soils have saturated conductivities measured at 2–7 mm/day (Grewal *et. al.*, 1987), resulting in high runoff rates.

Estimates of erosion rates in the Shivaliks are extremely variable. Assuming relatively high sediment delivery ratios from the small, steep watersheds, parts of the Sukhna catchment adjoining Dhamala are losing as much as 900 tons of soil per hectare per year (Bansal and Mishra, 1982). At an assumed bulk density of 1.8 g/cm^3, this represents average soil loss of 50 mm/yr, more than an order of magnitude greater than current estimates of uplift (Ives and Messerli, 1989). During the 1990 field study, the visual impact of erosion in the Shivaliks was immediately apparent:

> The [Sirsa River] floodplain is rich in alluvial deposits, composed partly of river boulders. In this low flow period, the river channel is braided, though evidence of flood damage is considerable. Along the banks where undercutting has taken place, stabilization appears rare, except for occasional gabion structures. This is attributable to the sole presence of round river boulders, unsuitable to the construction of masonry revetments.
>
> On the far side as we proceed through reclaimed fields; surface irrigation water indicates the low level of infiltration in these soils. Though the agricultural fields appear to have high sand content, there must be pan formation lower in the profile to result in all this ponding.
>
> The rise from agricultural land into the gullied watersheds of small *choas* is abrupt. Slopes approaching the vertical appear to contribute significantly to sediment in the checkdams. The matrix is essentially unconsolidated, loosely compacted sand and silt. Rill erosion has resulted in the isolation of grass clumps and exposure of their roots to termites. This aspect, NE, has significantly more precipitous slopes than the SW. [SW] slopes are gentler overall; the matrix appears to be more consolidated, resulting in fewer precipitous slopes. (Scott, 31 May 1990 Field Report, unpublished).

Detailed historical observations of conditions in the Shivaliks indicate that 46 years ago, erosion was extensive (Gorrie, 1946). Widely knowledgeable about erosional processes in the Himalaya and Shivaliks, Gorrie wrote:

> Geologically the whole of the Siwalik foothills...is so unstable that any form of grazing must inevitably lead to disaster. Merely by letting cattle graze for a few seasons, deep gullies appear, causing ruination of the natural grassland by destroying the underground moisture balance. (Gorrie, 1946: 60).

Gorrie's assessment of erosion indicated that degradation of the Ambala Shivaliks (including the Dhamala area) in the 1940s was reversible:

TABLE 1
Local Terminology for the Shivaliks' Environment

Local name	English equivalent
Landforms	
choti	peak, also high ridge
dakkar	moisture retentive soils
dhang	vertical cliff
ghati (kati)	valley
halka dhalan	medium to low slope
khud	chasm, as opened by erosive flow of water
lassa (dhang ka lassa)	debris collapsed from a vertical cliff
shamba	steeply sloped, denuded face of hard soil
siyoti	sloping land, suitable for rainfed agriculture
thapar	gently sloped, vegetated forest area of deep soils
tibbi	peak
Soils	
bajri	gravel
balu	sand
chhara	sodic soil, specifically agricultural
chikun	clay
daban	sediment
domut	literally, two soils; mixed soil
kalar	saline soil, specifically agricultural
kankar	stone, also hardpan
mulwa	organic matter
rode	pebbles
sil	boulder
Note: In addition to classifying soils based on texture as presented here, local knowledge further uses color; for example, *lal chikun* (red clay).	
Hydrology	
choa	ravine
jhiri	rill
nala	gully
nali	rivulet
Erosion Control	
daul	agricultural field bund
jhadi ki bad	brushwood checkdam, also brush fence
naka	stone barrier
nakabundi	gully plugging
tarwala dam	gabion reinforced checkdam
vatbundi	earthen contour bunding

> ...the stage of destruction already reached in Hoshiarpur and Ambala Siwaliks and the plains below them formed directly from their destruction in the past, is appreciably nearer to geological balance, and with the easier replacement of the plant cover with higher eastern rainfall [than in the western uplands, now in Pakistan], we ought in the nature of things to be able to put the whole process of destruction into reverse gear. (Gorrie, 1946: 12).

At present, valley bottoms, forest, and range lands in the Shivaliks provide the resource base for sedentarized pastoralists, the Hindu Gujjar, who still rely heavily on livestock, and the Sikh Jat who are primarily agriculturalists. Harijans (including the 'scheduled castes' of Chamar, Chunde, Darkhan, Lohar, and Theli), Jhivars, and Brahmins comprise a minority in the study area. Among the residents of Dhamala, there is a common knowledge pool of considerable depth and extent. The use, particularly among the Jat, of a variety of land capability, erosional, and hydrological descriptors suggests that such processes play an important role in resource use. Table 1 presents a summary of local terminology, separated into categories for different environmental characteristics. Much of the terminology is clarified and discussed in this section.

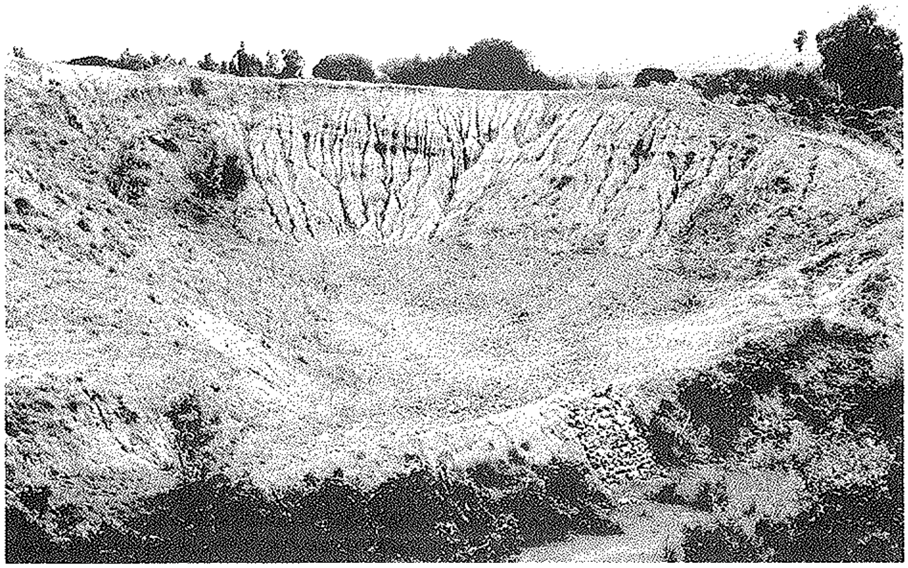

FIGURE 2. Dhamala residents level land by inducing erosion and causing in-field sediment deposition. Photographs by C. A. Scott.

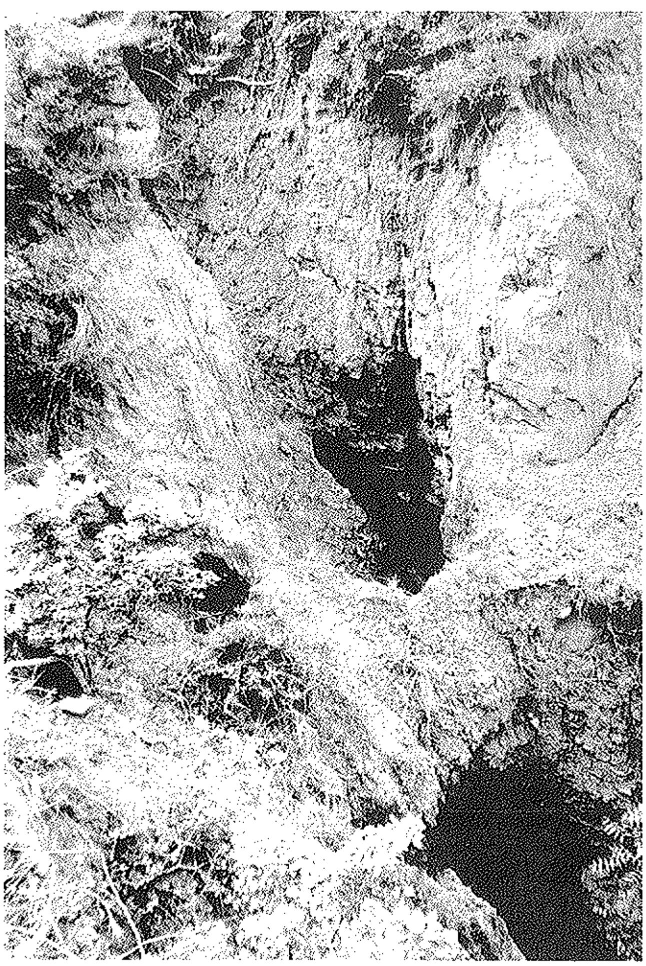

FIGURE 3. A *khud* (chasm) is formed by an erosive torrent. Safe disposal of excess runoff is of major concern to land users.

In Dhamala, an informant related: "*Dakkar* is good land, generally flat or lightly sloping, with *chikni mitti* (clayey soil) that retains moisture well." It may occur on hilltop plateaus, or in lower areas not filled in through sedimentation, that is, naturally occurring low-lying level areas. "Everything grows in *dakkar,*" he emphasized, "trees, grasses, and weeds." He pointed out an adjacent, undulating hilltop with slope up to 10% that had good growth of *khair (Acacia catechu)*, grasses, and shrubs. "That is also *dakkar.*"

Land filled in through sedimentation, or slightly sloping land behind any sediment control system is called *daban.* The soil remains moist, and is capable of supporting vegetation. Earthen field bunds are called *daul.* The process of natural levelling through deposition of sediment behind a field bund is referred to as *daban hona. Daban* is created in some cases through accelerated erosion and in-field sediment deposition, as shown in Figure 2.

Land-use practices in the Shivaliks are based on capability. Due to poor soil depth throughout much of the region, agriculture is restricted to the lands least affected by erosion. However, erosion-prone lands are used for grazing and the collection of minor forest products, primarily fuel and fiber. Non-agricultural lands of high productive potential include *thapar* (well vegetated, sloped forest land), and *dhang ka lassa* (debris collapsed from a vertical cliff). *Siyoti* is sloping land with sufficient exposure, where rainfed agriculture is possible if the soils are *domut* (silt loam) mixed with *mulwa* (organic matter). The link between erodibility and productivity is apparent, although the data are insufficient to establish a cause and effect relationship.

Lands with low productive potential are also the most erodible. These include *shamba* (steep clay slope which supports only sparse grass cover) and *choti* (high ridge).

Balu (sand) and *bajri* (gravel) are recognized as soils of low productivity because of low natural fertility and poor moisture retention characteristics. The soils lexicon is considerably more extensive for agricultural lands; however, we restrict ourselves here to the perceived linkages between soil type and erosion of the uplands.

Hydrologically speaking, *jhiri, nali, khud, nala,* and *choa* are all upland water courses of increasing flow and erosivity. The sudden concentration of runoff from intense rains is a major cause of *jhiri* (rill) and *nali* (rivulet) formation in agricultural lands. Where erosive flows drop from significant heights, as for instance from *nali* to *nala* (gully), *khud* (chasms) are created (Figure 3). A *khud* was observed to be forming in the middle of an agricultural field through rapid infiltration which caused piping, ultimately leading to the collapse of the field into the adjacent *nala.* Other fields had been lost as the result of this piping and slumping phenomenon.

Local knowledge concerning the ecology of plant species and their applicability for erosion control is considerable. *Bhabbar* grass (*Eulaliopsis binata*) is a perennial, deep-rooted bunch grass well suited to vegetative erosion control. That *bhabbar* is shade averse is self-evident to most Dhamala residents. However, that it is symbiotic with, and may be planted under *khair* (*Acacia catechu*), which does not have a dense canopy, is equally clear, as explained by an informant. There appear to be many potential applications of local knowledge for vegetative erosion management to complement structural approaches.

Conventional techniques have been adopted in the Shivaliks and many have been adapted by residents. The shortage of stone suitable for the construction of *naka* (gully plugs) makes this technique difficult. *Nakabundi* (stone gully plugging) and *vatbundi* (earthen contour bunding) are often used for moisture enhancement on pasture and forest lands; infiltration results from ponding behind the bunds. *Daul* (field bunds) are used primarily in agricultural fields and may be reinforced using a perennial grass such as *jhoond* (*Sacharum manja*) as shown in Figure 4. *Jhadi ki bad,* or brushwood checkdams, are often used to control erosion as well as for fencing around fields to keep out livestock and wild animals. If made with such tree species as *jhingan* (*Lania coromandelica*), brush checkdams may root and establish themselves permanently.

A watershed conservation project to reduce sedimentation in downstream Sukhna Lake was started in 1978 in the Shivalik Hills adjoining Dhamala. Sukhomajri and Dhamala were pinpointed as the source of huge amounts of sediment, and considerable effort was invested in ravine (*choa*) reclamation through the construction of gabion-reinforced revetments, drop structures, and stone gully plugs. Vegetative barriers of *Agave* were planted to stabilize eroding slopes while commercially valuable tree and grass species were planted to increase canopy. Small masonry weirs were installed to trap sediment and prevent its transport downstream to Sukhna Lake.

The local residents' primary objective was to manage erosion to increase the productivity of their resource base. They were interested in irrigation from earthen water-harvesting dams (Figure 5) and in planting forest produce with local or commercial value. Irrigation allows intensification of agriculture which serves to reduce pressure on erodible forest lands. To increase biomass productivity, the villagers voluntarily restricted grazing in the watershed in a process called 'social fencing,' an innovative alternative to barbed wire and forest guards. Cut-and-carry rules for fodder grass induce villagers increasingly to switch to buffaloes which give high yields of milk. Residents now have rights over locally valuable timber and grass species and patrol the forest more actively.

While it would be an over-simplification to claim that a cause and effect relationship exists between reduced erosion and increased productivity, changes in both over the past sixteen years indicate that a strong correlation exists. With irrigation, fertilizers, and appropriate slope stabilization techniques, agricultural yields for wheat have increased 120% (Grewal *et al.,* 1990). Through social fencing and appropriate erosion control measures, biomass productivity has increased 50% for *khair,* 100% for *bhabbar,* and 600% for fodder grasses (Scott, 1991). The resulting annual increase in average household income has been 15% (Chopra *et al.,* 1990). Simultaneously, sedimentation in Sukhna Lake has been reduced, as shown in Table 2. While rates of erosion cannot be equated with rates of sedimentation, we have pointed out that the sediment delivery ratio of small, steep watersheds is high. The data presented indicate that the combined approach has effectively addressed the dual objectives of increased biomass productivity and sediment control. Local initiatives to control soil loss on the agricultural and grazing lands, where most of the erosive flows are generated, are supplemented by conventional techniques applied to the eroding gullies and ravines.

RESOURCE TENURE AND MANAGEMENT

We have shown that local residents and soil scientists articulate complementary responses to erosional processes in Dhamala. However, in order to sustain an approach that mitigates erosion in the Shivalik Himalaya over the long term, local institutional capability must be able to apply and manage appropriate measures and techniques. Furthermore, the approach must effectively address the erosion hazard of lands critically at risk. Zurick's (1990) study of resource management in Nepal questions the communal focus of many rehabilitation programs. That study addresses the mix of private and communal resources, suggesting that farmers are more

FIGURE 4. Field bunds are reinforced using *jhoond* grass (*Sacharum manja*).

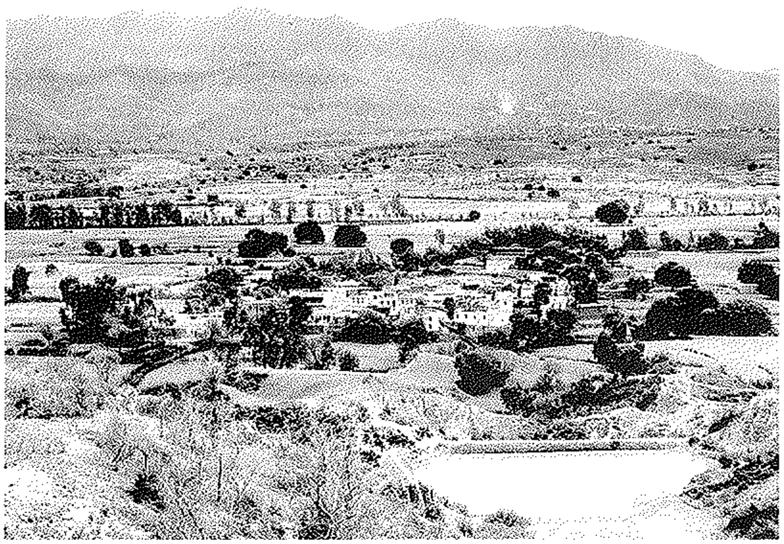

FIGURE 5. Irrigation from water-harvesting structures allows intensification of agriculture (background) which serves to reduce pressure on erodible forest lands (foreground).

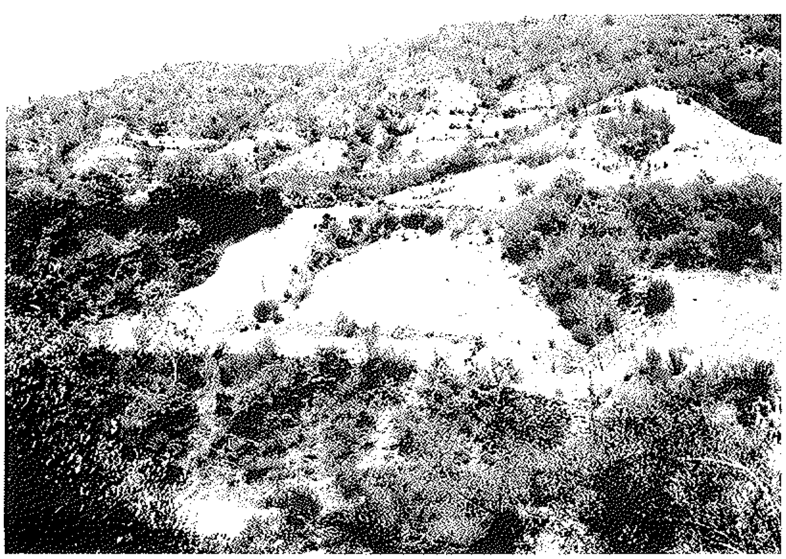

FIGURE 6. Erosion results from cultivation of *shamlat deh* (individual usufruct common land) in the forest. Note the stone barriers built to capture the lost soil.

TABLE 2
Sediment Inflow in Sukhna Lake from the 3,214 ha Shivalik Hills' Catchment

Period	Average annual sediment inflow (ha/m)	Average sediment yield* (t/ha/yr)	Cumulative reduction (%)	Comments
1959–64	55.0	308.0	—	No systematic efforts made to control erosion or reduce sedimentation
1968–71	40.0	224.0	27	Structural erosion control and sediment transport reduction implemented
1979–82	4.4	24.6	92	Combined land-use and erosion/ sedimentation control implemented

*Assuming bulk density = 1.8 g/cm^3
Source: Bansal and Mishra, 1982.

likely to invest time and effort in the rehabilitation of their own holdings. We suggest that private holdings are likely to be better endowed, i.e., with higher 'biophysical capabilities' (Zurick, 1990: 24), and consequently receive higher levels of labor and nutrient input. The communal focus of many development schemes is rightly directed, in our opinion, towards common lands, which are at greater risk of degradation and erosion, in part due to their poorer natural endowments.

A significant amount of land in the Shivaliks is neither private nor state-owned, but falls in the category of common land. Erosion of these lands is often pronounced. *Shamlat* is the general term for village common land. *Shamlat* can, in turn, be further divided into *charand* (also *charaga*, or grazing land) and *shamlat deh* (also *dei shamlat*, or common land in which usufruct is vested in the names of individuals). No outside resident has use rights (*huk*) in *charand*. Rights in *shamlat deh* are transferable through inheritance, even outside the village, though in no circumstance may rights be sold. *Shamlat deh* in the reserved forest is being cleared and levelled for agriculture (Figure 6). Erosion resulting from the cultivation of *shamlat deh* is considerable. The individual with use rights to this piece of land has built stone barriers to capture some of the lost soil. However, degradation of strictly common *shamlat* and *charand* lands can be effectively addressed only through community-wide institutions. Yet, traditional management institutions are disappearing.

The *Rakha* (forest watchkeeper) was a traditional functionary in Central Himalayan communities (Kiran Bhatia, 1990, personal communication). The village council appointed one or more village members to monitor forest resources, with remuneration provided in kind through village-wide contribution. In each community, norms existed for resource extraction (Moench and Bandyopadhayay, 1985). For example, only live branches of a certain minimum diameter could be cut for their leaf fodder. Fuelwood could not be cut green; instead, only dried branches were used. In the absence of the present, insatiable external demand for forest produce, resources were managed sustainably to meet local needs. With resource extraction for urban markets, forest resource degradation has intensified. The increase in commercial demands on forest resources throughout India in the past century has resulted in the breakdown of local management institutions (Gadgil and Iyer, 1989). In the Shivaliks, for example, the forest department now pays the *Rakha* a daily wage, usurping his accountability to the community and vesting it in the department.

An interesting example of local cultural practices that act to conserve resources is provided by a small Devi (goddess) temple atop a hillock in the reserved forest adjoining Dhamala where villagers come to do *puja* to the Goddess. Vegetation surrounding the shrine has a noticeably more dense canopy than adjoining areas of the forest, while rill erosion is less pronounced. An informant related that Devi protects the forest, that fuelwood collection here is forbidden by her wish, and that the *pujari* (priest) watches for violators. All this takes place within the forest department's jurisdiction. A forest department official explained that, in his view, the basic issue relating to the existence of the shrine is not that the community manages the resource, but that further 'encroachment' be restricted, i.e., that construction of the shrine not be extended. Although the legal and traditional uses of this piece of land are not in accord, both act to conserve resources.

The emphasis of the forest department's current program is collaborative in nature. This 'joint management' forms the context for the complementary implementation of local knowledge and conventional science approaches to soil erosion. The forest department is currently collaborating with some 45 local village communities in the Shivaliks in a similar joint management approach. Extension materials have been developed which link local terminology for landforms with appropriate erosion management techniques (Scott, 1990). The combination of land-use planning with erosion control has been extremely effective in meeting the objectives of local land users and soil conservationists.

CONCLUSION

We have shown that local knowledge systems in the Shivalik Himalaya and conventional soil science formulate different, though complementary, responses to erosional processes. Both are limited in their effectiveness in mitigating erosion hazard. Local knowledge is specific and approaches erosion hazard from a land-use perspective. As a result, local responses to erosion take effect in the human/ecological timeframe and emphasize the spatial separation of intensive land uses from erosive landforms. The land-use approach is currently constrained by the shortage of uncultivated land and by demographic changes in the region. Conventional science is general and prioritizes structural and vegetative techniques that may be rapidly implemented in the agricultural timeframe to reduce erosion and sedimentation. The erosion control emphasis of conventional science means that techniques are usually implemented at the actual site of erosion hazard. Geomorphic activity in the Himalayan region that results in catastrophic soil movement events constrains the erosion reduction approach.

The case study of the Shivalik Hills demonstrates the complementarity of local and conventional approaches to erosion in Dhamala village. Prioritizing the productivity of forest and agricultural land, Dhamala residents reduced grazing pressure on erodible land by selectively using fodder and fiber grass in a cut-and-carry system. They spatially moved agriculture away from erodible lands and further intensified it by irrigating with water from earthen dams which also reduce the erosivity of flows. In the conventional scientific approach, stone gully plugs, sediment traps, and ravine training structures were implemented to reduce sedimentation of Sukhna Lake. It was found that if contour bunds were implemented at the site of tree and grass plantation, biomass productivity increased significantly. Such coupling of local land use with conventional techniques for erosion control has been successful in meeting the productivity objectives of land users and the sediment reduction objectives of soil conservationists.

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