Chapter 2
Lateritic Badland of Sinhati, Bankura, West Bengal: A Geomorphic Investigation

Ankan Aown and Nabendu Sekhar Kar

Abstract Located 4 km NW of Bishnupur town in the Sinhati area of Bankura district, a localized badland has developed in a north–south orientation over the Pleistocene lateritic sediments on the left bank of the River Birai, a tributary of the Dwarakeshwar River. The climatic condition of this region is ideal for development of lateritic badlands by water erosion. Three gully networks have been identified over this 50.8 ha area with dominance of lower-order streams indicating high erosional rates by overland flow and surface runoff. The mean bifurcation ratio is 4.1. A four-facet slope profile is developed here with a lateritic duricrust and mottled layer clearly representing deep weathering. The western section of the badland is more erosive than the eastern section. Typical micro- and mesoscale landforms were recognized, such as escarpment, cliff, duricrust, rills and gullies, gully fans, and so on. The traditional fish breeding practice by embanking gullies makes this badland the most revenue-earning site of the area, which marks it an exception against the general perception of nonproductive badlands. The indigenous technique of fish breeding also acts as an effective measure of restricting soil erosion which can be followed elsewhere. But increasing numbers of commercial fish-breeding farms, resulting from growing market demand, pose a threat of accelerated soil erosion at Sinhati.

Keywords Laterite Gully erosion · Badland · Duricrust · Soil erosion management

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2.1 Introduction

The western part of West Bengal can be divided into two distinct physiographic zones: the degraded part of the Chotanagpur Plateau in the west and plateau fringe fans in the east. These fans are comprised of old alluvium, transported by western tributaries of the Bhagirathi–Hugli River, which coalesces with the Ganga delta in the east (Bandyopadhyay et al. 2014). The major rivers flowing on this plain are the Dwarka, Ajoy, Mayurakshi, Damodar, Darakeshwar, Shilabati, and Kangsabati, among others. Lateritic badlands are common in this plateau fringe plain, traditionally known as the *Rarh Plain*. These low-level lateritic badlands are considered to have originated in situ over the unconsolidated secondary deposits from the high-level sources during the Pleistocene, and reworked later by subaerial weathering (Oldham 1939; Niyogi et al. 1968; Chakraborty 1970; Mallik and Niyogi 1972; Basu 1972; Niyogi and Mallik 1973; Chakrabarty 1985; Bandyopadhyay 1987, 1988; Mukhopadhyay 1992; Das and Bandyopadhyay 1995, 1996; Sen et al. 2004; Dey et al. 2009). Niyogi and Mallik (1973) identified this belt of laterite covering an area of 1000 km^{-2} running approximately NNE–SSW from Farakka through Kharagpur as the Worgram/Kharagpur belt which merges with the coastal laterite tract of Odissa. Ghosh and Majumdar (1981) alternatively suggested that the primary laterites in this belt, capping the alluvial deposits, were reworked and deposited as secondary laterites at a physiographically lower but stratigraphically upper part during the Middle to Late Pleistocene. Laterites are also found at higher levels in the western degraded plateau.

Badlands are barren lands with no or little vegetation cover, very rugged, inaccessible, and of very little or no economic value, developed by active rill and gullying by running water. Localised badlands in the districts of Puruliya, Bankura, Birbhum, and West Medinipur districts of West Bengal have been reported on the above-mentioned laterite belt by many scholars (Shome and Raychaudhuri 1960; Bhattacharya 1957; Goswami 1980; Biswas 1987; Bera and Bandyopadhyay 2013; Laha 2011). Extensive studies on evolution, development processes, channel and drainage character, slope character, and profile character have been carried out. The majority of the works are concentrated specifically on badlands Garhbeta of West Medinipur (Kar and Bandyopadhayay 1974; Bera 1996; Bandyopadhyay 1988; Das and Bandyopadhyay 1995, 1996; Sen et al. 2004; Dey et al. 2009) and Khoai of Birbhum district (Bandyopadhyay 1987; Mukhopadhyay 1992; Das and Bandyopadhyay 1996). Although several localized badlands are reported along the banks of various rivers in Bankura district, intensive study on the badlands of the district are rare.

Located 4 km NW of Bishnupur town in the Sinhati area of Bankura district, a localised badland is developed over the lateritic sediments on the left bank of the River Birai, a tributary of the Dwarakeshwar River. The present work aims to study the processes responsible for its development, analyse its profile and drainage character, and identify the typical landforms developed on it.

2.2 Database and Methodology

The Sinhati badland (23°05′16″N to 23°05′34″N and 87°16′6″E to 87°16′24″E) is situated on the left bank of the River Birai, a tributary of the Darakeshwar River. It falls under the Sinhati village of Ramsagar Gram Panchayat (local administration), located 4 km NW of Bishnupur town of Bankura district, West Bengal (Fig. 2.1).

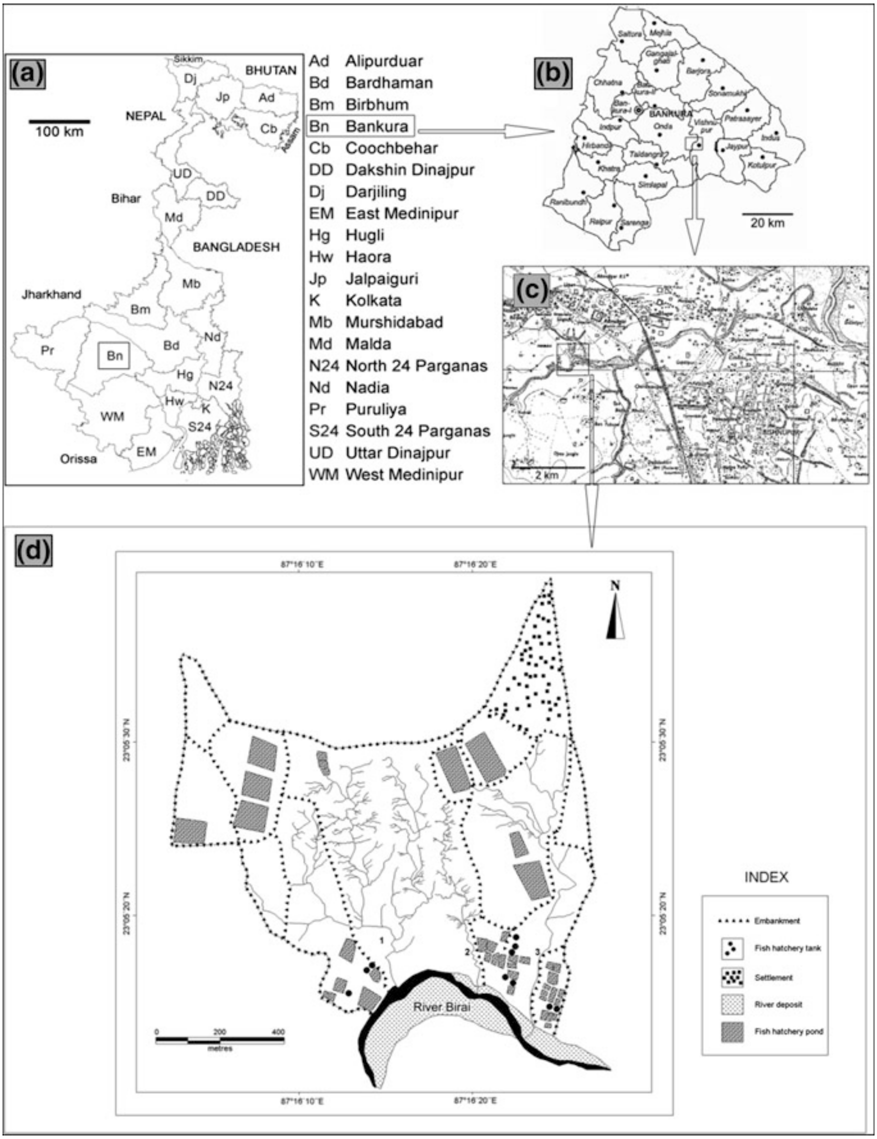


Fig. 2.1 Sinhati badland (**d**) is located 4 km NW of Bishnupur town (**c**) of Bankura district (**b**) of West Bengal (**a**). Three major gully networks annotated *1*, *2*, *3* in (**d**) are responsible for badland development

With active ravine and gully erosion over a lateritic escarpment facing the River Birai, a localised badland was formed in a north–south orientation. This badland covers only a small area of 50.8 ha and is in an early stage of development.

Secondary information on geology and formation of various lateritic badlands of the western part of West Bengal were collected and studied. For the base map, Survey of India topographical sheets (73 M/8 and 73 M/4 on 1:50,000 scale) surveyed in 1970–1972 and CNES/Astrium image (17 Feb 2014) downloaded from the Google Earth platform were used. Information on the geology of the area was obtained from a geological map of Bankura district, published by Geological Survey of India (GSI 2001) and meteorological data were collected from IMD (India Meteorological Department), Alipur office, Kolkata.

The ground survey was conducted using tape, clinometer, Abney level, and GPS (etrax 76csx) to study slope, gully side development, and profile character. Erosional intensity was measured following R.P.C. Morgan's method (1986; Morgan 2009); that is, number of first-order streams × length of the first-order streams per unit area. The mean bifurcation ratio was calculated after Strahler (1957). Various micro- and mesoscale landforms were identified also. Collected data were mapped using PCI Geomatica and Map Info software. Profiles were drawn with field data using Microsoft Excel.

2.3 Results and Discussion

2.3.1 Pluviometric Influence

The monthly average temperature data of 1971–2010 show that high temperature prevails more or less throughout the year in this area and monthly average rainfall data (1971–2010) shows that this region remains dry except the monsoon months (June–October) with 90 % of the annual rainfall (Fig. 2.2). This humid tropical monsoon climate is ideal for laterite development (Thomas 1974; Faniran and Jeje 1983; Battaglia et al. 2011). Short-spanning high-intensity monsoon rainfall over the bare lateritic surface of Sinhati, developed by indiscriminate forest cutting, is also favourable for the formation of badland topography.

Various kinds of water erosion are responsible for the formation of the badland, which are rain-splash, nonconcentrated flow such as sheet flow, and concentrated rill and gully erosion. Stream bank collapse, subsurface piping, slumping, and mass movements were also noticed.

Some morphometric exercises were done to map the intensity of pluviometric processes over the area. First, stream orders were identified following Strahler's law which clearly suggests active erosion by lower-order streams. The highest stream order was identified as fifth order (Fig. 2.3) and the mean bifurcation ratio was 4.1,

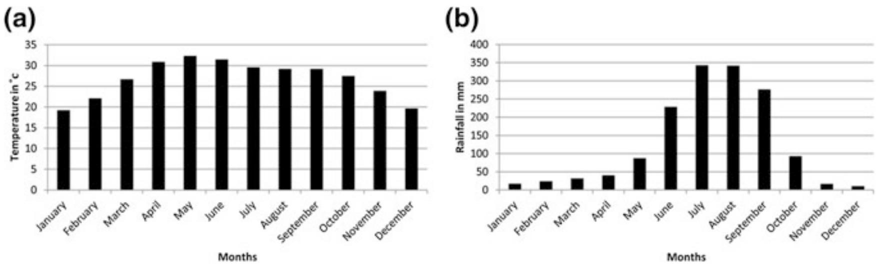
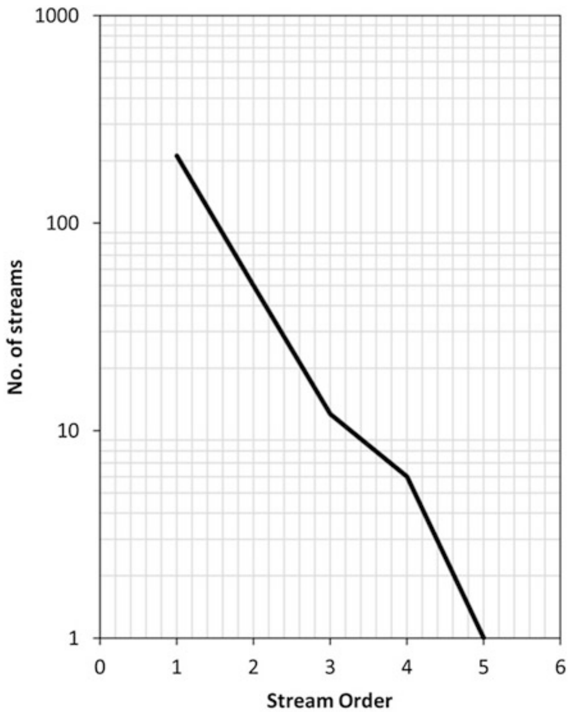


Fig. 2.2 Average (1971–2011) monthly temperature (**a**) and rainfall (**b**) trends of Sinhati are clearly related to the formation of lateritic horizon here (*source* India Meteorological Department)

Fig. 2.3 Relation between stream order and number of streams clearly shows the dominance of lower-order streams indicating a high rate of erosion. Mean bifurcation ratio of gully networks of Sinhati is 4.1



which is very high for an area of 50.8 ha. Three major gullies (annotated 1, 2, and 3 in Figs. 2.1d and 2.4a) were identified in the region flowing north–south following the regional slope located in the eastern, middle, and western sections, respectively. The networks of gullies 1 and 2 were separated by a divide whereas gullies 2 and 3 were parted by an embankment built by locals. The natural badland development process of gully 3 was hampered by fish farming activities. Details of the gully network and gully side slope characters are shown on Tables 2.1, 2.2 and 2.3.

Table 2.1 Classification of Gullies at Sinhati Badland

Rill/gully type	Numbers	% of total gully network	Depth (m)	Average width (m)	Side slope (°)	Characteristics
Small	211	75	<1.5	<3	<10	Initial ephemeral channels, unstable and change courses with every shower; comparatively matured ones are distinct to the naked eye and relatively stable; occupy the zone of maximum erosion; headward erosion is prominent
Medium	66	24	1.5–3	3–7	10–30	Small rills coalesce or widen; channels are quite prominent and stable; during shower act as active transporter of sediments
Deep and narrow	3	1	>3	>7	>30	Most distinct and stable with high side slope; carry large amount of water and sediments during wet season

Table 2.2 Details of gully networks at Sinhati badland following Strahler's law of stream ordering (1957)

Gully network	Details	Stream orders				
		1st	2nd	3rd	4th	5th
Gully 1 (West)	Numbers	129	35	7	3	1
	Length (m)	45	12	6	3	12
Gully 2 (Middle)	Numbers	56	12	3	1	0
	Length (m)	12	56	3	3	0
Gully 3 (East)	Numbers	24	4	3	2	0
	Length (m)	11	2	2	10	0

Table 2.3 Gully side-wall types at Sinhati badland

Gully side wall type	Cause of development	Zone of occurrence
Sloping	Rain wash, creep, rill development	Northern midwestern part where small and medium gullies dominate
Vertical	Mass movement	Southern zone occupied by deep gullies

2.3.2 Slope and Profile Character

An east–west cross-section of the badland is shown in Fig. 2.4. From this section it is found that the deepest among the three gullies is gully 1 located on the western section of the area (Fig. 2.4b).

It was revealed from the erosional intensity map (Fig. 2.5) that the midwestern section of the Sinhati badland is most erosive. Sides of all three major gullies showed a four-facet profile comprising a top layer of hardened duricrustic materials (~ 1 m) overlain by surficial soil, subrounded quartz pebbles, and loose pisoliths (murram) with diameter ranging between 0.3–2 mm. Below this layer a section of mottled clay and sand was found with orange patches (~ 2 m) underlain by a thick facet (~ 1.3 m) of pallid ash-white cemented materials of fine sand and clay. A dark layer of very fine (~ 1 m) sand and clay was found below it (Table 2.4).

As recorded in a humid tropical environment (Young 1972; Thomas 1974; Faniran and Jeje 1983), the major processes of profile development are lateral erosion and parallel retreat of slopes. These processes are also active in the Sinhati badland. The eastern side of gully 3 was analysed (Fig. 2.4b) to discover the slope segment characteristics (Fig. 2.6).

2.3.3 Landforms

Denudation and deposition gave rise to different meso- and microscale landforms at Sinhati (Fig. 2.7).

Lateritic duricrust: Rock weathering and pedogenesis in a humid tropical climate result in the formation of duricrust. The duricrust of Sinhati, overlying the mottled and pallid horizons, signifies deep weathering (Fig. 2.7a).
Escarpment: An escarpment of ~ 10 m height was formed on the left bank of River Birai due to bank erosion (Fig. 2.7b).
Cliff: Cliffs were formed here either by lateral erosion of gully side walls or mass movement (Fig. 2.7c).
Rills: Rills are typical features of badlands. Here intensive networks of rills show the initial signs of water erosion by overland flow and surface runoff (Fig. 2.7d).

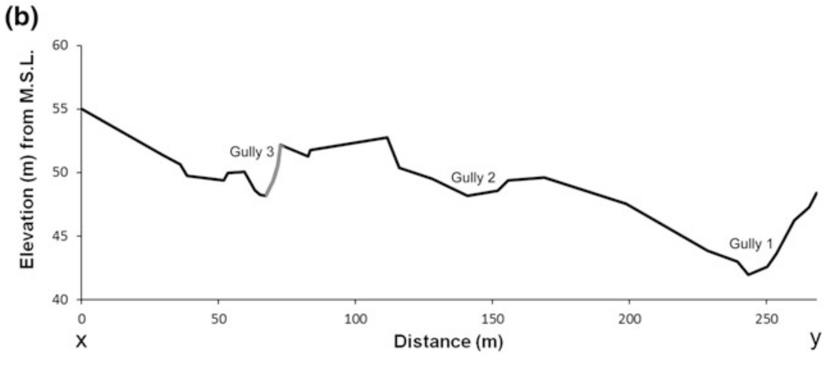


Fig. 2.4 CNES/Astrium image (17 February, 2014) downloaded from Google Earth platform shows the landscape of the area. A cross-profile (*xy*) is drawn with the help of Tape, Abney's level, and GPS shown in (**b**). Gully 3 (*ash colour* part of the section in **b**) side wall horizons are shown in Fig. 2.5

Table 2.4 Lateritic profile of Sinhati badland

Facet	Dominant process	Declinity (°)	Thickness (m)	Characteristics
Surficial soil, subrounded quartz pebbles and pisoliths	Disintegration by mechanical and chemical weathering, surface wash and overland flow.	85–90	~0.2	A surface cover of red soil eroded in many places. It is a weathered duricrust with pisoliths and subrounded quartz pebbles.
Duricrustic layer	Mechanical and chemical weathering. Head and lateral erosion		~1	Hardened layer of nodular duricrust containing iron concentration.
Mottled layer	Chemical and biological weathering, leaching	60–65	~2	A layer of fine sand and reddish mottled clay; partly cemented.
Pallid layer	Leaching, sidewall erosion	20–25	~1.3	An ash-white layer of cemented fine sand and clay.
Dark clay layer	Lateral erosion and basal deposition of eroded materials	10–15	~1	Greyish layer near the gully bed containing very fine sand and clay

Gullies: Three major defined gullies were identified in western (Fig. 2.7e), middle, and eastern sections, respectively (Figs. 2.1d and 2.4a). Average depth of the gullies from their beds is ~5 m.

Gully fan: All three gullies have produced gully fans where they meet the River Birai. The largest of them is created by Gully 1 (Fig. 2.7f) with a maximum width of 15.8 m.

2.3.4 *Land Use and Management of Soil Erosion*

The Sinhati badland is unique from the point of view of anthropogenic use (Fig. 2.1d). In general badlands are considered unproductive. But in the case of Sinhati, it is the most revenue-earning site of the area. This is the famous fish breeding ground of Bankura district. Fish hatchery ponds were built at the end of gullies by embanking them. During the monsoon season overland flow and surface runoff are stored here. These ponds also act as sediment catchponds. These ponds silt up with eroded materials within a cycle of 5–6 years. Then the fish breeders leave the silted ponds and build new ponds at the end of other newly formed gullies. It is a traditional practice here and quite effective in managing gully erosion.

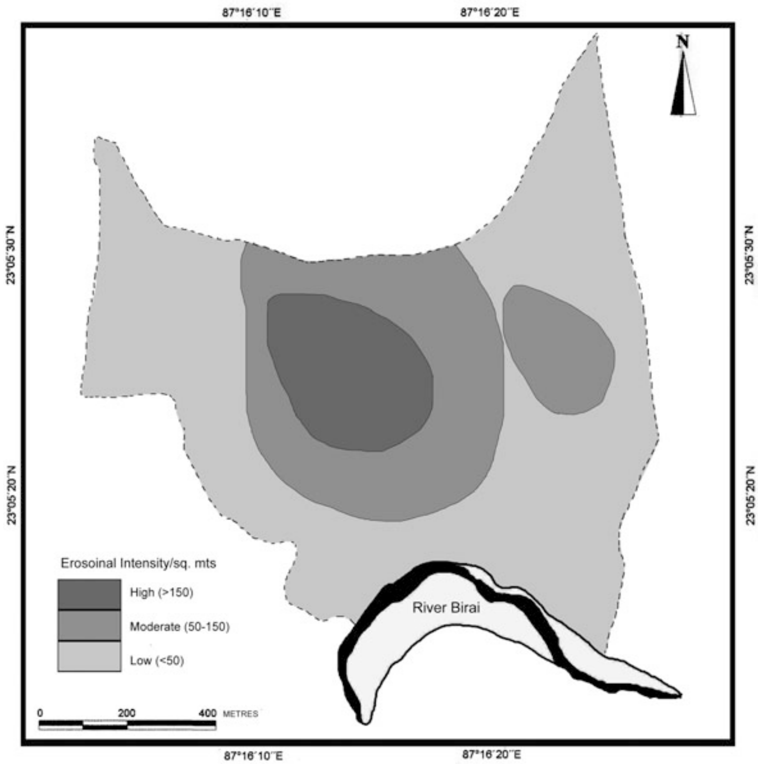


Fig. 2.5 Erosional intensity map of Sinhati Badland shows maximum intensity of erosion concentrating at north-midwestern section due to maximum density of small and medium sized gullies

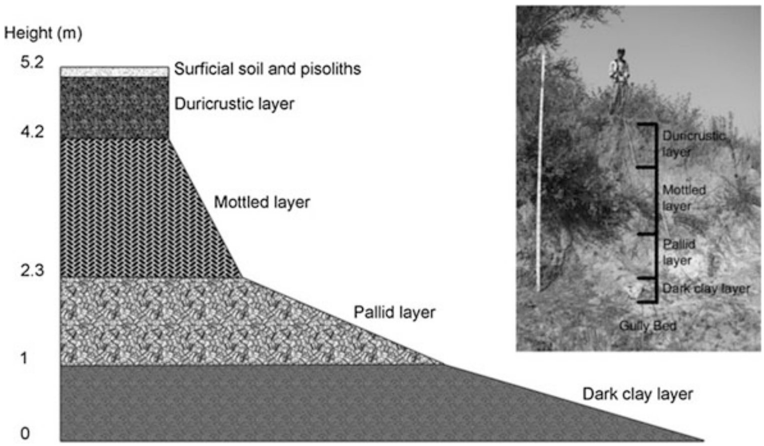


Fig. 2.6 Schematic sketch of eastern side wall of Gully 3 shown with the typical horizons formed over lateritic terrain of Sinhati. Heights indicative of thickness of horizons from local base level (*gully bed*)

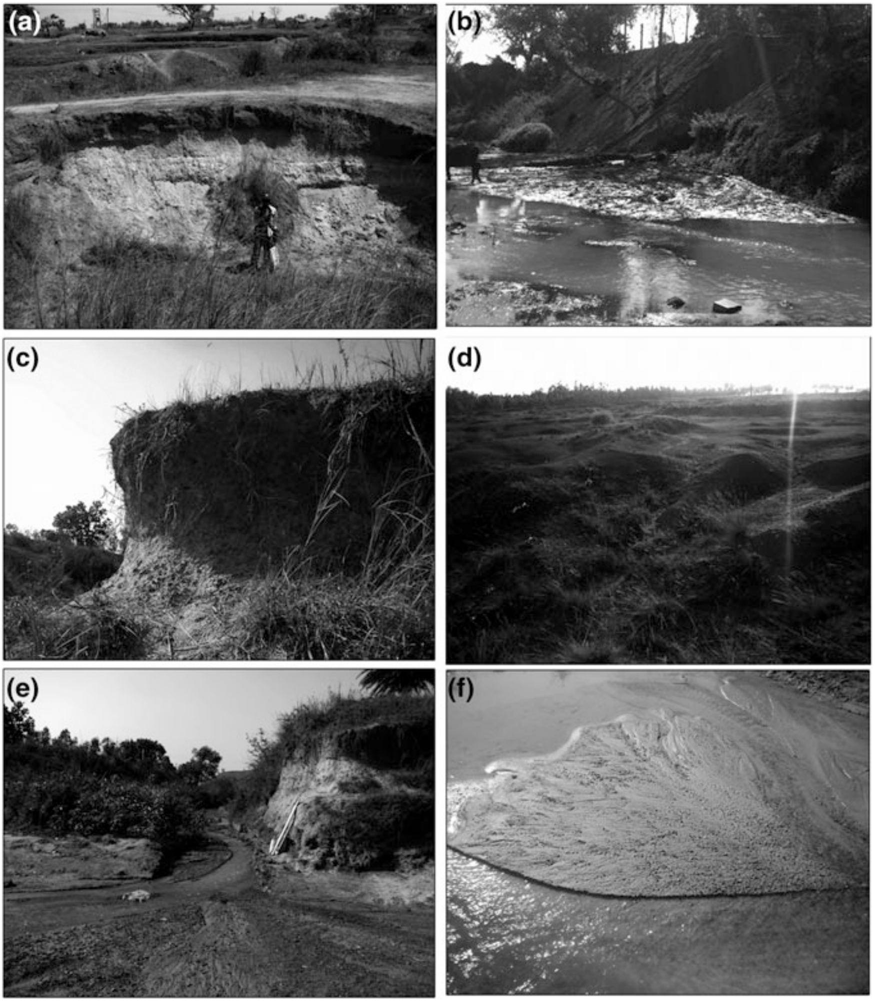


Fig. 2.7 Typical micro- and mesoscale landforms of Sinhati badland. **a** Laterite duricrust, **b** escarpment located on left bank of River Birai, **c** cliff formed by gully erosion, **d** rills, and **e** gully and **f** gully mud fan created by Gully 1

With increasing demand and commercialisation fish breeders are coming to this site and fish breeding practice migrates towards the head of the gullies (Fig. 2.8). This will lead to aggravated erosion of the badland and it should be restricted immediately.

As in the southern section near the River Birai, fish farms for their interest control and check soil loss; a management plan should be formulated by incorporating this traditional practice. Small check dams and bunds must be built at the source area of the gullies, that is, the northwest part where the maximum

Fig. 2.8 Increasing numbers of fish-breeding farms posing threat of accelerated soil erosion at Sinhati

concentration of rills is seen resulting in the maximum rate of corrosion. Mulching, plantation, and grass cover might be good options for restricting soil loss in this source area.

2.4 Concluding Note

Accelerated erosion in lateritic badlands is a major concern of soil erosion management in the tropical world. Various measures are taken for restricting erosion and increasing production of this type of lateritic terrain. Some are conventional techniques including construction of check dams and other sediment-catching structures or modern techniques such as extensive afforestation, biomatting, or chemical matting and the like, aimed at controlling accelerated erosion mainly for the development of agriculture. But in the case of Sinhati, the traditional sustainable practice of use of the badland as a very productive fish breeding ground serves as an operative soil erosion controlling technique. This gives us a new way of thinking about the management of badlands. Instead of cropping, badlands can also be used for other purposes.

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