Geomorphological Field Guide Book

on

CHAMBAL BADLANDS

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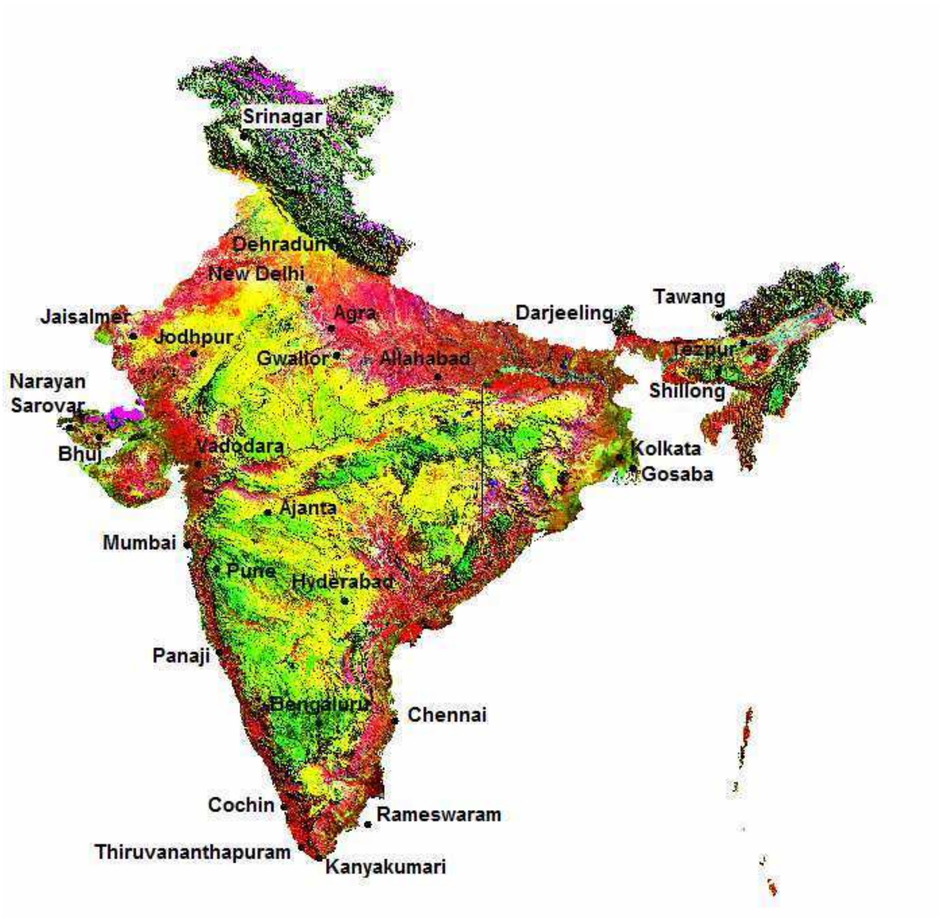

Fig. 1. Image-map of India, showing some places of interest for the 9th International Conference on Geomorphology, 2017 (Map prepared by A. Kar through processing of relevant ETM+ FCC mosaics and SRTM 1km DEM, both sourced from the US Geological Survey site). Boundaries are approximate.

Geomorphological Field Guide Book on Chambal Badlands

Itinerary

Day	Places from - to	Stay
Day 1	Arrival at Agra Visit in and around Agra	Agra
Day 2	Field visit to Sahso, Bindwa Khurd and back to Agra	Agra
Day 3	Field visit to Emiliya and back to Agra Depart from Agra	

A. CHAMBAL BADLANDS: AN INTRODUCTION

Land degradation is considered to be one of the most severe global environmental challenges (Eswaran et al., 2001; Lal, 2001; Scherr and Yadav, 2001). It has numerous economic, social and ecological consequences. Land degradation is also an important geomorphic process in many parts of the world and in a range of landscapes. Its causal determinants, in terms of local specificities, are yet to be understood fully (Lambin et al., 2003, 2009). Gully initiation and evolution, like many other processes of land degradation, has been attributed to diverse natural and anthropogenic causes (Burkard and Kostaschuk, 1995; Dregne, 2002; Wells and Andriamihaja, 1993). Natural causes of ravine erosion include climate change (Poesen et al. 2003), catastrophic storms, and isostatic rebound, tectonic uplift or base level lowering (Begin et al., 1981; Ouchi, 1985). Removal of vegetation and deforestation (Bensel, 2008; Ireland et al., 1939; Quiggin, 2009; Singh and Agnihotri, 1987), overgrazing (Quiggin, 2009; Wells and Andriamihaja, 1993), population pressure, institutional settings and public policy (Blaikie, 1989; Boardman and Poesen, 2006; Anand and Herath, 2003; Stocking and Murnaghan, 2001) are among the significant anthropogenic factors causing land degradation (Pani and Carling, 2013).

Fig. 2. A view of the Chambal Badlands.

The Chambal Badlands (26°17′15″ to 26°52′22″N, and 76°28′30″E to 78°32′55″E) occurs within the catchment area of the Chambal River that originates from the Vindhyan Ranges in the Indian Peninsula, and is one of the most degraded areas in India (Fig. 2). It occupies 4989 sq. km area in the states of Uttar Pradesh, Madhya Pradesh and Rajasthan. Much of the badlands in the visit area have developed in the catchments of the Chambal River flowing in SW to NE direction and its tributary, the Kunwari River, which flows from south to north and then northeast and meets the

Chambal on its right bank. The deep networks of gullies developed here are known for their ruggedness and high inaccessibility. It is also infamous for centuries for the outlaws. We provide here a short overview of the physical and cultural aspects of the area.

Physical Features of the Area

Climate

The area falls within the limits of the semi-arid and the sub-humid regions. Moderate rainfall, high temperature, dry summer and cold winter are the main features of climate here. The three main seasons are summer (March-June), rainy (July-September) and winter (October-February). Summer is mostly dry and hot, when the mean maximum temperature rises to 42°C in May, but the winter is mild, with a mean minimum of 7°C in January, although it is not uncommon to experience >45°C during summer and 1-3°C during winter. The mean annual rainfall varies from 765 mm at Agra to 796 mm at Morena, while Delhi to the north of the area receives 714 mm annually and Gwalior at the south receives 900 mm. Much of the rainfall is received during July-September, the season for summer monsoon rains, when about 90% of the total annual is received.

Geomorphology

The route from Delhi to Agra and from there to Morena-Bhind area falls within the vast Ganga Plains (Fig. 3). The area from the foothills of the Hiamalayas to the lower Chambal valley near Gwalior can be broadly subdivided from north to south into three geomorphic units: (1) Piedmont Zone (PZ), (2) Central Alluvial Plain (CAP), and (3) Marginal Alluvial Plain (MAP) (Agarwal et al., 2002; Goswami and Mishra, 2014; Singh, 1996). The landform units in the area can be grouped under three genetic types, viz. fluvial, denudational and structural origin. Landform units of fluvial origin are the alluvial plains, flood plains, river terraces, ravinous zones and valley fills. Landform units of denudational origin include the residual hills and buried pediments, while the landform units of structural origin include the mesa, buttes and plateaus. The alluvial plains cover almost fifty percent of the area.

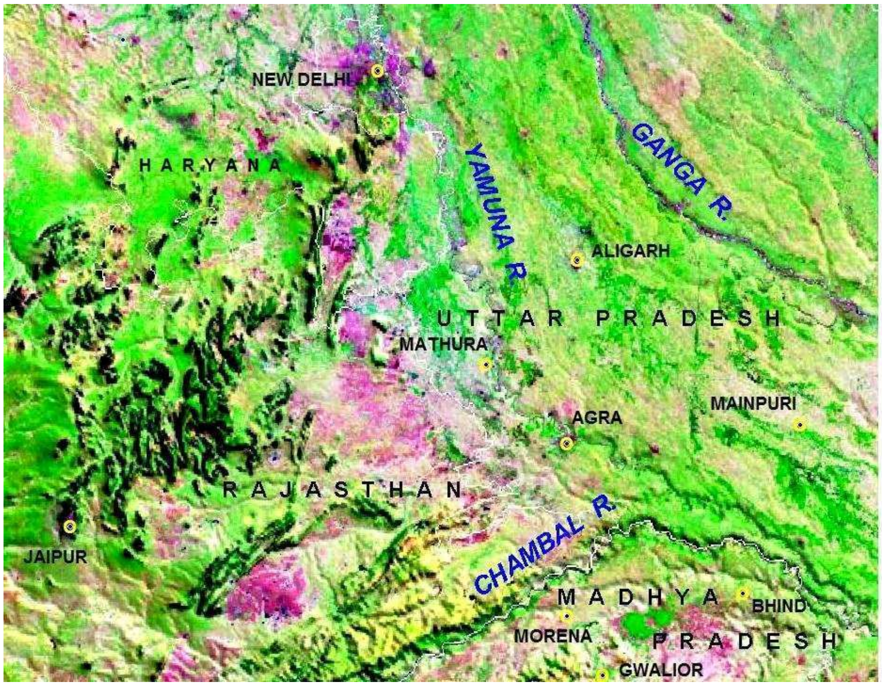

Fig. 3. ETM+ FCC mosaic, draped on SRTM 1km DEM, to show the terrain characteristics of New Delhi-Agra-Morena-Bhind area.

Chambal River is a major tributary of the Yamuna that originates from the Himalayas**.** The ravines are formed on both sides of the Chambal River and its tributaries. The total basin area of the Chambal River is about 143219 sq. km. The average gradient of the river in lower Chambal valley is 0.21m/km (Jain et al., 2007). The main tributaries of the Chambal are the Chamla, Kshipra, Kalisindh, Mej and Parvati. The Chambal serves as a major source of hydro-electric power generation, irrigation and fisheries for Madhya Pradesh and Rajasthan States.

A major part of the visit area in Morena-Bhind tract is under a thick alluvium deposited by the Chambal River and its tributaries (Fig. 3). The area of interest, the Badlands, come under the Marginal Alluvial Plain, which is enclosed by the Yamuna River and the Indian craton, where the land is characterized by an intricate network of gullies along the Chambal, the Betwa and the Yamuna Rivers as well as along their tributaries (Ranga et al., 2015a).

Chambal Badlands are extremely dissected, difficult to cross and is agriculturally unfit. The area between Bhind and Morena is the most dissected, with an irregular topography, and consists of steep ridges, low hills, deep trenches and broad incised meanders (Fig. 4). The area is also dotted with small hillocks of Vindhyan sedimentary formation within the Chambal Valley and its ravines, which are separated from the main expanse of the Vindhyan Range. A number of isolated hills are scattered also in the alluvial tract. Limestone and sandstone constitute the residual hills having moderate relief of the order of 240-260 m.

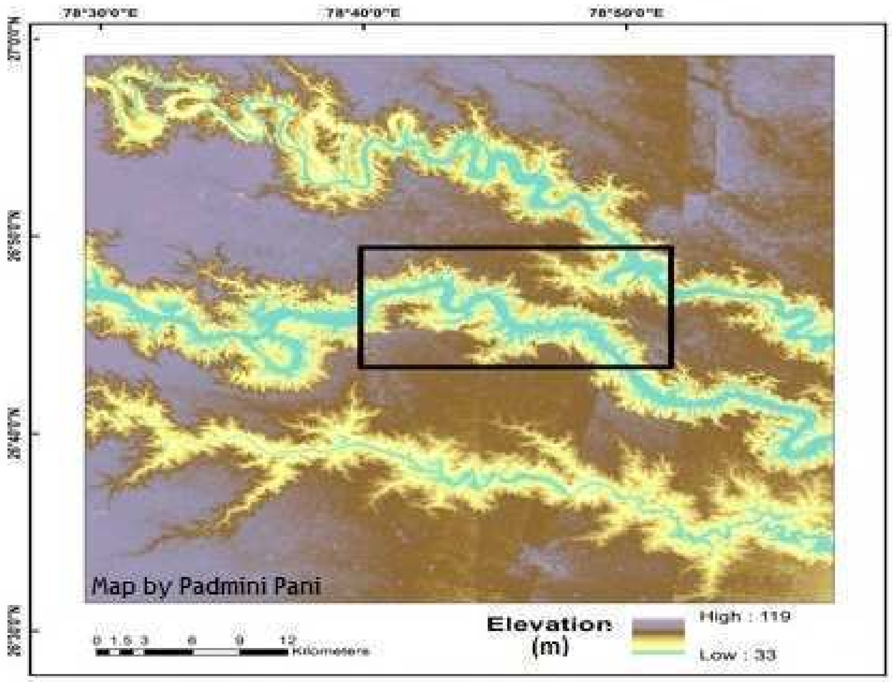

Fig. 4. ASTER DEM (30 m) to show the rugged topography of the Chambal Badlands. Box shows the Morena-Bhind area.

Fig. 5. A gully in the foothills..

Badlands in the lower Chambal valley have incised a former active floodplains (which is now inactive), and have formed a narrow valley. Steep ridges, low-sloping hills, deep trenches and broad meanders are common features of the area (Fig. 5). The general slope of the area is towards north-east (Pani and Carling, 2013). Steep scarps form the boundary between the badlands and the adjacent inactive flood plain (Fig. 6). At many places leveling activities on such scarps can be noticed, where the boundary becomes vague and land use becomes transitory (Ranga et al., 2015b). The active flood plain is restricted to the narrow incised valley, marked by point bars on the concave curves of meanders, which are formed by meander cut-off and lateral migration of the river. The palaeo-channels are all observed in the inactive floodplains which are now used for cultivation purpose (Ranga et al., 2015a).

Fig. 6. A steep scarp between the badlands and the Chambal River.

Apart from the Chambal, the main river flowing in the Badlands area to be visited is the Kunwari River (Fig. 7). It emanates from the Vindhyan Hills in Shivpuri district of Madhya Pradesh, and then flows in north-east direction through the Vindhyan scarps in Bijaipur, Jora, and Sabalgarh tehsils. This river is the major source of fresh water supply in the area. When it enters the Morena plain, it forms deep ravines and wipes out much of the nutrients of the plain (Singh, 1978). The river flows through a hilly tract and joins the Chambal River. The drainage pattern is mostly dendritic to sub-dendritic. All rivers generally flow from south to north or north east and meet the Chambal River on its right bank. Drainage density is high in the valley portion and in the plains.

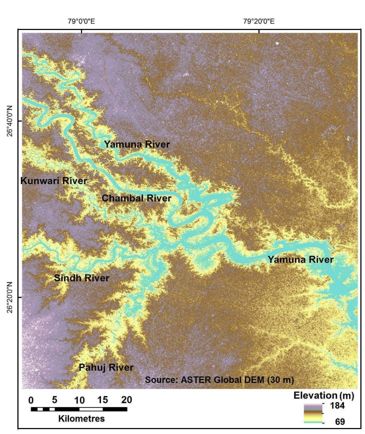

Fig. 7. ASTER DEM (30 m) of the ravines along the Chambal River and its major tributaries near the Chambal-Yamuna confluence.

Soil

Soils of the lower Chambal valley vary widely. In the soil map of India, the Lower Chambal Valley falls within the limits of two main soil groups, viz., the reddish grey and the yellowish brown alluvial soil. In general, the soils have a surface colour of pale brown to yellowish brown with patches of greyish tinge. In the visit area the soils are broadly of two types: (i) sandy loam to loam with low phosphorous and salt content, and (ii) clayey loam with low phosphorous and salt content (GoMP 1996; Pani and Carling, 2013).

Vegetation

The natural vegetation consists of various kinds of thorny, shrubs and trees, including Berry, Dhou, Kardhai, etc. The forest mostly comprises of small thorny bushes not consisting of any thickly grown trees, except in some parts of the valleys. However, in some parts of Tonga, Mala and Navez valleys taller trees of Dhau, Mahua, Jamun, Palas (Tesu), etc., are also present. The ravine land is generally devoid of a good vegetation cover. The predominant species in ravine area are mostly Anogeissus pendula. The significant minor forest products are Tendu (Diospyros melanoxyloan), Khair (Acacia catechu) and Harra (Terminalia chebula).

Socio-economic Aspect

The historical records related to the area can be traced to the ancient time. Although there are scanty historical records to indicate when ravine erosion became noticeable, Habib (1963) designated badlands in India as a pre-Mughal phenomenon (i.e., before 1526 AD), but no historical records were found to trace their formation (Singh & Agnihotri 1987). The Chambal administrative division is densely populated, and a large section of the population lives in rural areas. Although the inhabitants of Chambal area belong to multiple religions and castes, the word Chambal has become almost synonymous with dacoits. Dacoity would not have gained such anchorage here, but for the favourable geographical/terrain conditions. The intricate gully networks, the ruggedness of the topography, and the least opportunity for agriculture in an undulating dry terrain have all helped the dacoits a safe heaven away from the glare of the law.

The sprawling ravines indeed make for excellent hideouts. The socio-economic reasons include a high density of rural population in the plains surrounding the badlands and within it in small patches, that dominantly depend on subsistence agriculture, increased fragmentation of land holdings over time as the population rises, inability to spread cultivation into the badlands area or to gainfully utilize that vast barren land for agriculture, non-availability of other employment opportunities and adequate infrastructures, as well as a sense of isolation. Frequent droughts were also a factor to coop with. The region has a long history of droughts that make rain-fed cropping somewhat uncertain. Occasionally excessive rains also lead to crop loss and food shortages (GoMP, 1996). Despite this, the rural poverty in Morena is less than expected.

Fortunately, situation started to improve gradually since the 1970s when a series of development activities were undertaken to improve the land condition, to provide infrastructural and other facilities, and to help the inhabitants in getting a better return from the resources available. Now the problems of dacoity are almost non-existent.

A sample survey in several villages has revealed that about 80% of the inhabitants depend on cultivation and dairy, while the rest are mostly carpenters, weavers, agricultural labours, wage earners, etc. Most of the families are of middle-income group. Literacy rate is, however, low (38%). As against the rural head-count poverty of 37% in Madhya Pradesh, the poverty in Morena was 21% in 2004-2005, while the urban poverty ratio was 42%, which was almost at per with the state's urban poverty of 43% (Chaudhuri and Gupta 2009; GoMP 2007; Pani and Carling, 2013).

The medical facilities were very few in the area till recently. Only a few dispensaries used to run by the State Government; so the people had to depend more on traditional medicines. The situation is now gradually improving. Low literacy level of the families has been responsible for a general lack of awareness about sex education and child health care.

About 80% of the families, though, have some knowledge about ravines and their formation, types and reclamation. These people are quite aware that the ravines affect the fertility of the soil. As infrastructures, canals, and services have started to link the area with other neighbouring areas, vast changes have started to take place in the socio-economic fabric of the area.

Major Land Uses: Of the gross cropped area, food crops accounted for 55.65%, and non-food crops account for 44.35% of the area in 2007–2008. During 2005-2008 nearly 66% of the net shown area was under irrigation. Canals, tube wells and wells are the main sources of irrigation in the area. Canal irrigation is a recent phenomenon in the area, and includes two canals, the Morena Branch Canal and the Ambah Branch Canal. During the pre-canal period wells were the major source of irrigation, and irrigated area was highly restricted. With the construction of the Chambal Main Canal, on an average 17933 ha of land is now irrigated every year. Rain-fed agriculture in the region is characterized by low productivity and low levels of marketable surplus.

Badlands along the lower Chambal valley are now getting levelled manually (Fig. 8). The use of tractors and bulldozers has transformed some parts of the badlands as a rolling topography. Completely or near-completely flattened land is normally found either in the sufficiently wide valley bottoms within the badlands or in the remnants of the dried channel meanders. The more undulating levelled lands are the work of tractors or bulldozers, with clear signs of scouring (Ranga, 2013; Poesen et al., 2006).

The question of sustainability of agriculture here, as elsewhere, mainly focuses on production over an extended scale of time and space. This essentially would mean that crop production and economic gains would flourish over a long period of time, almost infinitely and globally (Shah, 2006). It encompasses a range of strategies for addressing many of the problems such as loss of productivity from excessive erosion and associated plant nutrient losses, surface and groundwater pollution from pesticides, fertilisers, and sediments, impending shortage of non-renewable resources, and low farm income from depressed commodity prices and high production cost (Parr et al., 1990). Moreover, agricultural sustainability implies a time dimension and the capacity of a farming system to endure indefinitely (Lockeretz, 1988; Kumar and Pani, 2013).

Fig. 8. Land levelling for cultivation in the badlands area.

B. DESCRIPTION OF THE FIELD SITES

Day 1
Arrive at Agra
Stay at Agra

The day will be spent in discussing the details of the visit and in sight-seeing in and around Agra.
In order to appreciate the badlands landscape in next two days, a review of badlands formation and control measures is provided below.

Badlands Characteristics, Processes and Control Measures

Among the diverse types of land degradation in India, ravine is one of the severe forms, where the loss of top soil has major economic implications. There are four major ravine zones in India: the Yamuna-Chambal ravine zone, the Gujarat (Tapti, Narmada, Sabarmati, Mahi) ravine zone, the Chota Nagpur ravine zone, and the Shiwalik Foothills (Punjab) ravine zone. Of these four zones, the Yamuna-Chambal ravine zone is the largest (Sharma, 1980), and the badlands along the Chambal and its tributaries are the most severely incised and degraded (Sharma 1979). The adverse effects of the ravine erosion in the lower Chambal valley go far beyond the removal of valuable topsoil on which plants depend for their nourishment. The direct effects include gradual decline in crop yield and engulfment of agricultural land by ravines. Thus, the proximate impacts of ravines are highly concentrated in agriculture. In some cases, these impacts are so intense that farmers have to shift their settlements (Pani and Mohapatra, 2001b). Further, the spill-over effects of gully erosion gradually impinge on the livelihoods of people in varying ways (Pani, 2012). The interrelationship between economic processes and land degradation in this region, like elsewhere, is multilevel and complex.

Gullies are formed due to localized surface runoff affecting unconsolidated terrain. Initially gullies are emerged from rills, which are few centimetres deep. Regardless, after impact of heavy rainfall and wearing action of runoff, its size of degradation increases (NRSC, 2011). Majorly Madhya Pradesh, Chhattishgar and Jammu & Kashmir states are severy affected by the ravines problem. In 2008, Morena (MP), Bilaspur (Chhattisgarh) and Rajauri (J&K) had more than 5% degraded land of their total geographical area (TGA) affected by gullied and ravines. In 2005, the number of degraded districts with >5% under ravines was more than in 2008: Morena, Bhind in MP, Rajauri, Pulwama in J&K, Bilaspur in Chhattisgarh, Bundi in Rajasthan, and Chandigarh in Punjab (Priya and Pani, 2015).

Characteristics of the badlands: Badlands are characterised by highly dissected topography with steep slopes where inter-rills, rills, gullies and ravines form integral parts. The different types, such as deep ravines (Fig. 9), moderate gullies (Fig. 10) and shallow gullies (Fig. 11), can be identified in the Chambal Badlands area. The advancement of the gully networks takes place especially through headward erosion of individual gullies (Fig. 12). Various stages of formation of the ravines in the area can be summarised into (a) swallow hole stage (Fig. 13), (b) piping stage (Fig. 14), and (c) collapsing stage (Fig. 15).

Being an agriculture-dependent economy, India suffers great economic loss to badlands (Ranga et al., 2015b). The lower Chambal valley accommodates badlands covering an area of about 4800 sq. km (Sharma, 1979). Initiation and formation of badlands are considered to be an effect of Himalayan orogeny (Ahmad, 1968; Sharma, 1968; Agarwal et al., 2002) and probably also due to intensification of southwest monsoon between 15–5 ka ago (Gibling et al., 2005). Due to Himalayan orogeny, the fore-bulge of Himalayan foreland basin (Gibling et al., 2005; DeCelles, 2011) experienced an uplift (Agarwal et al., 2002) which forced the Chambal River to attain a new equilibrium. On attaining the new equilibrium, the Chambal River incised into its own deposited sediments and in the due process, badlands, on both sides of he Chambal River, came into existence (Sharma, 1979; Pani and Mohapatra, 2001, Poesen et al., 2016).

Fig. 9. A deep ravine in the Chambal Badlands.

Fig. 10. A moderately deep gully in the Chambal Badlands.

Considering the significant contribution of agriculture to economics, the focus of badlands studies was always on reclamation with Government of India (GoI) support. Early known attempts to assess badlands encroachment were made by Sharma (1979), who used Survey of India (SOI) topographic sheets, field observations and interviews with local farmers to map the badlands. He found badlands encroachment rate varying from 20 to 40 cm per year. Later, Haigh (1984) suggested that India's badlands continued to expand at the rate of 1% per decade. In the subsequent years, GoI (1996; as cited in Deshmukh et al., 2011) reported a reduction in areas covered by badlands from 3.97 million ha in 1971 to 2.67 million ha in 1996. However, this reduction figure of about 33 % was severely criticised by Deshmukh et al. (2011) who suggested that the approach was mere in-room discussion and lacked ground survey. Recent publications still suggest that badlands are encroaching into the croplands, engulfing fertile land and thus posing a great threat to the regional economy (Pani and Mohapatra, 2001; Joshi 2014; Poesen et al, 2016).

Fig. 11. A shallow gully in the Chambal Badlands.

Fig. 12. Headward erosion of a gully in the Chambal Badlands.

Fig. 13. Swallow hole stage of badlands formation.

Fig. 14. Piping stage of the badlands formation.

Fig. 15. Collapsing stage of the badlands formation.

Process of formation: Badlands fascinated dissected topography, unconsolidated soils or poorly consolidated bedrock for the same reasons that inhibit agricultural uses, like lake of vegetation, steep slopes, high drainage density, shallow to non-existent regolith and rapid erosion rates (Bryan and Yair, 1982; Howard, 1994; Poesen et al., 2003). Such areas are commonly affected by intense processes of soil erosion, including gulling, rilling, and sheet wash erosion (Nadal-Romero et al., 2008, 2010; Shit et al., 2013). Gullying is one of the most important erosion processes, largely contributing to the sculpturing of the earth surface over the last decade. The advancement of gullies has many pessimistic impacts as it usually engrosses the loss and the deposition of a great amount of soil (De Ploey, 1990; Marzolff et al., 2011). Moreover, the development of gullies entails an amendment of overland flow, shortening of runoff lag time and an increase in runoff volume. Many efforts have been made to understand the main factors and processes of gully formation (Boardman, 2006). Deforestation played a major role for gully erosion in developing countries. Removal of vegetation by logging or cropland spreading out in humid areas, or by overgrazing in semiarid zones, favours the advancement of gullies (Bull and Kirkby, 2002; Marzolff et al., 2011). Gullies perhaps develop through different, concurrent factors. Poesen et al. (2003) stated that inter-rill flow tends to concentrate downslope into pathways leading to a more efficient flow and to a decrease in flow resistance. It follows that the interaction between overland flow and ground surface roughness is a process relevant to gully initiation (Poesen et al., 2006; Govers et al., 2007; Campo-Besco et al., 2013). Expansion of gully continues being influenced by flow resistance and morphological characteristics of the features (Ries and Marzolff, 2003; Seeger et al., 2009; Shit et al., 2014).

Causes of formation in India: In India, ravine erosion is one of the prominent processes of land degradation. Recent literature has focused on ravine mapping and classification using optical and high- resolution remote sensing data (Sujatha et al., 2000; Dwivedi and Ramana, 2003; Chatterjee et al., 2009; Pani and Mohapatra, 2001b). These studies emphasized deforestation, overgrazing and unsuitable farming practices as causes of gully erosion (Sharma, 1980; Haigh, 1984; Singh and Agnihotri, 1987; Pani and Mohapatra, 2001a, 2001b). Gully erosion gets further aggravated due to the intensity and concentration of rainfall during the monsoon, as well as due to the erodibility of the thick alluvial soils where most of the ravines develop (Sharma, 1980). Specifically, the relative significance of climatic factors in ravine formation in India has been a source of debate (Haigh, 1984; Pani et al., 2005). Most of the studies favour multiple combinations of socio-economic and biophysical factors rather than any single set of factors responsible for ravine formation (Sharma, 1980; Pani et al., 2005; Pani et al., 2011; Pani and Carling, 2013).

Control measures: Regional vegetation knowledge can be very useful in effective control of soil erosion through aerial seeding in Chambal valley. Adams (1987), on finding the seeding effort being ineffective, suggested grass buffer strips for the same purpose. The grass or other vegetation type for this purpose should be summer-tolerant to be effective (Ranga et al., 2015b). Vegetation activity in badlands is also indicative of erosion processes. Vegetation has a stabilizing affect to soil erosion; in Chambal valley increase in vegetation after the monsoon may be indicative of reduction in soil erosion whereas on the onset of monsoon, due to least vegetation activity, soil erosion could be drastically high.

Socio-economic implications: The interactions between social and natural processes impacting upon land degradation are often complex and locale-specific (Blaikie, 1985). Land degradation has several socio-economic implications, including loss of agricultural land (Pani and Mohapatra, 2001a, 2001b), agricultural productivity (Biggelaar et al., 2003), worsening food security (Scherr and Yadav, 1996), lower levels of economic activity and low standards of living (Ezaza, 1988) and poor health status (Scherr, 1999). Land degradation has been affecting the livelihoods of many primary producers in Asia and Africa (Joshi et al., 1996; Scherr, 1999; Scherr and Yadav, 1996, 2001). Damage caused by gully erosion is found to be most severe in the alluvial plains of the semi-arid and arid zones in the developing world, where it threatens precarious subsistence-oriented agricultural systems. Gully reduces the size of agricultural land and also affects productivity through changes in hydrological conditions, soil structure and accessibility (Zglobicki and Baran, 2012; Pani and Carling, 2013).

Badlands constitute dynamic environments where they are formed, expand and disappear or are deleted following the changes in the equilibrium between natural processes and human activities (Torri et al., 2000). In arid and semi-arid regions where vegetation is very sparse and soils are rich in clay minerals, severe erosion induces the badlands, characterized by steep slopes with rills and gullies as their main features (Liberti et al., 2009). The badlands of the Chambal valley are now subjected to levelling for agriculture, but the levelling is not sustainable and requires continuous efforts (Ranga, 2013). Monitoring of badlands becomes an important aspect for policy making and environmental planning (Poesen et al. 2012).

Day 2
Agra to Sahso, Bindwakhurd and surroundings, and back
Stay at Agra

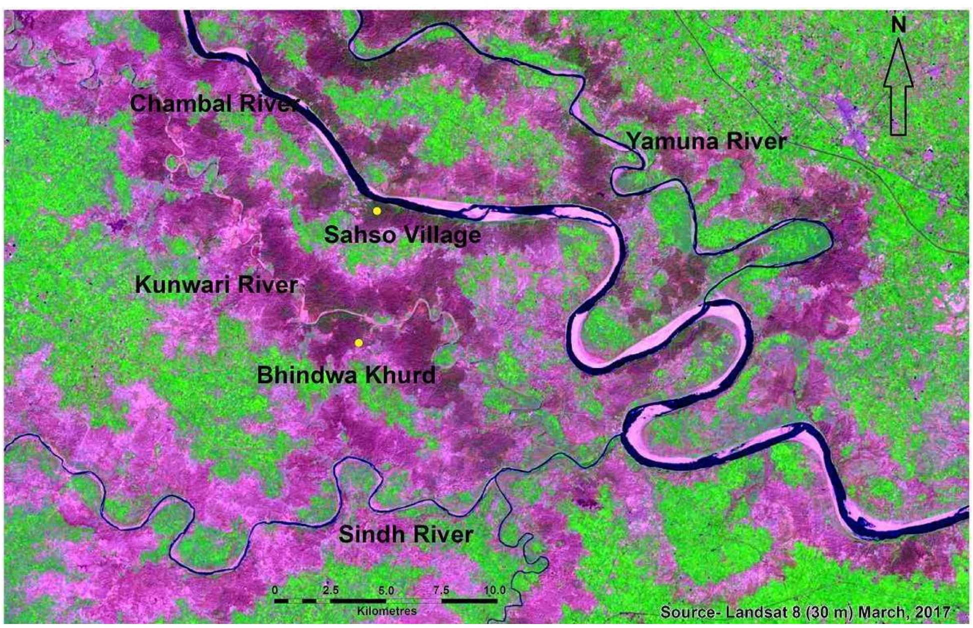

Fig. 16. Google earth image of the area to be visited on Day 2.

The field trip to village Shaso and Bindwakhurd and its surroundings will be undertaken to see the severe ravine-affected terrain and the village landscape (Fig. 16). The much-discussed origin of ravine in peninsular India is of a geological origin and it has been suggested by many authors that this part has been rejuvenated in the recent geological past and the present topography has been carved out by accelerated stream action (Sharma, 1980). The entire stretch of river Chambal from Agra to Etawah, comprising of deep pools of water, can be seen as a glimpse of incised meander on the way to the study villages. Several deep, medium and shallow ravines exist together around the villages. Some classification is necessary to analyse the morphological characteristics of the ravine in this stretch. The depth of the ravines varies from 5 m to 60 m and more, with very narrow to wide base width (5-20 m) and steep side slopes. Most of the ravines appear here in "V" shape, which is developed where the soil and sub-soils are commonly friable and easily cut by flowing water. It can be observed that the active gullies are in linear shape, and most of the gullies are very narrow, deep, and associated with long gullies (sometimes more than 5 km) which are most of the cases very uncontrollable by nature. The vertical caving section of a ravine head is characteristic of a very active gully which is very much prone to engulf the unaffected adjoining land which is most of the cases agricultural land. The other pattern of the ravines is also very much present here like bulbous, compound and trellis pattern, which are quite interesting to study to understand the stages of growth of the ravine. Some part of the ravine also eroded and lowered down due to the natural process mainly by collapsing process. At the same location of Sahso and Bindwa Khurd villages, the local farmers' dwell with the ravine land and its encroachment is very much noticeable.

Day 3

Agra to Emiliya Village and back to Agra

Depart from Agra

Fig. 17. Google earth image of the area to be visited on Day 3.

The day will be spent in visiting sites near Emiliya village in Uttar Pradesh, around a meander bank of the river Chambal (Fig. 17). The area is the confluence zone of the Yamuna River and the Chambal River, a very interesting study site. Distinct fluvial landforms, deeply incised drainage system, and morpho-tectonic features are very much observable in this region. It is also well known for badlands having a labyrinthine network of deeply incised gullies and ravines with a variable depth of 50 to 60 m at places along the rivers. The discharge capacity, degree of incision, and channel width and depth of Chambal River is significantly more than that of the Yamuna in this stretch. Hence, the Chambal constitutes the trunk stream of the region.

According to Geological Survey of India (GSI), "The river course downstream of the Chambal-Yamuna confluence, which is at present known as the Yamuna, entirely due to mythological and historical reasons, has the same channel geometry and gradient as that of the Chambal River upstream of the confluence. This suggests that the Yamuna, in reality, follows the course of the Chambal River below the confluence of the two rivers" (www.portal.gsi.gov.in/gsiDoc/pub/cs_morphotectonics.pdf). Thus the area gives an insight to the origin of ravines and role of morphotectonics in the formation of badlands.

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