CHAPTER-1

1. Introduction

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Land and water are the most precious gift of nature to the humankind (Tong, 2018). With the climatic change, land degradation has emerged as the biggest challenge to the world, humanity and the economy (Bao Le et al., 2014). Since the last century, due to the expansion of industries, unplanned colonization, overgrazing and over-exploitation of other natural resources, degradationof land resources has increased considerably (Liu et al., 2004; Li et al., 2012; Hammad and Tumeizi, 2012). Land degradation leads to the loss of soil quality and productivity turning the landinto infertile and low yielding one to cultivate (Doran and Parkin, 1994; Doran and Jones, 1996; Lal, 1997). Land degradation is a broad umbrella under which multiple issues related to degradation and deterioration of land, like desertification, soil erosion, soil salinization, etc. are discussed. Almost every country in the world is facing the problem in either of its forms. In a global context, about 70% of land in Asia, Africa and the Americas is degraded; whereas, in Australia half of its land is degraded (Cardy, 1994). In India about 30% of its total geographical area (97.85 Mha) is degraded (NBSS & LUP, 2012). In that 80% of land degradation is caused bysoil erosion; making soil erosion a matter of serious concern.

Soil erosion is a natural process that leads to the detachment of soil grains by geological agencies like water, wind etc. However, soil erosion caused by water is a dominating factor in splash, sheet, rill and gully erosion. Splash erosion is the process of detachment of soil grain by the power exerted by raindrops. When rainfall occurs to a

greater extent and runoff moves in a relatively flatter surface (<1degree), it causes sheet erosion. If the runoff gets concentrated on channels and caused, erosion is characterized by rill erosion; and when the intensity of erosion is more and has a deeper incision into the ground, called gully erosion. Rill -gully - channel erosionis the characteristic feature of the badland topography.

1.1 Definition of the Badlands

Badlands are multivariate, self-enhancing systems of erosive processes which are characterized byintensely dissected topography with iterative patterns of rill-gully-channel networks having deteriorated soil properties reduced soil fertility and sparse vegetation (Tignath et al., 2005; Deshmukh et al., 2010 and 2011). These are poor agricultural landscapes in a range of low- permeable but normally erodible materials and can occur in various climatic conditions (Bryan and Yair, 1982). Gallart et al. (2002) have described badlands as loose unconsolidated sedimentaryterrain, with less or no vegetation cover. Harvey (2004) has defined badlands as a land of high incision on soft sedimentary terrain with higher drainage density of rill and gully and is dominatedby overland flow with thin vegetation in varied environmental conditions. The term “badlands” refers to regions that have soft and poorly consolidated material outcrops, limited vegetation, reduced or no human activity and a wide range of geomorphic processes, such as weathering, erosion, landslides and piping (Martínez-Murillo and Nadal-Romero, 2018).

1.2 Formation of the Badlands

This erosional topography is common in semiarid region with dry and hot summer and dry and cold winter (Yair et al., 1980; Alexander, 1982; Harvey, 1982; Imeson, 1983; Sdao et

al., 1984; Berndtsson, 1988; Alexander and Calvo, 1990; Howard, 1994; McCloskey et al., 2016) and not so abundant in humid and sub-humid climates (Bryan and Yair, 1982; Campbell, 1989; Regüés et al.,1995; Pardini et al., 1996; Torri et al., 2000; NadalRomero and Regüés, 2010).

The badlands can be classified into three major classes of their occurrences (Gallart et al.,2002) viz. (a) arid badlands characterized by dry climate (< 200mm precipitation), geologically controlled (b) semi-arid badlands characterized by moderate rainfall (200-700mm), discontinuousherbaceous cover and a combination of human-induced degradation and natural processes (c) humid badlands receives heavy precipitation (>700mm) with a good vegetation cover and has anthropogenic control. Badlands are very common all over the globe. It can be found on every continent except Antarctica.

The origin and formation of the badlands depend on various factors viz. slope, upliftment,change in rainfall pattern, land pattern change, deforestation and overgrazing, ill-considered tillage, over-drafting, an incompetent Physico-chemical property of the soil, anthropogenic activity, etc. (Kaul 1962; Tejwani 1959; Haigh 1984; Bull and Kirkby, 2002; Marzolff et al., 2011Tignath et al., 2005; Chaudhary et al., 2013). It is also observed that multiple factors may act together to carved the gully wall and form badland topography (Moreno-de las Heras and Gallart,2016).

Upliftment and erosion are two sides of the same coin and these processes occur simultaneously (Penck, 1953). On a regional scale, tectonic forces are elementary in badlands formation (Harvey, 1987; Grove and Rackham, 2001; Wainwright and Brazier, 2011). Tectonic uplift enforces local base level that allows the stream network to deep incise

the terrain. It ultimately results in deeper and broader gully systems as well as multi storey badlands system.

Badlands primarily develop in soft sedimentary terrain and are generally composed of soluble cement and less cohesive soil grains. In such cases, the physical property and mineralogyof soil play a significant role in the formation of badlands (Gallart et al., 2002). The bedrock lithology is essential to know the genesis of the soil horizon and the mechanical property of soil. Consequently, it controls weathering and erosion processes and is considered as a key badlands formation factor (Solè et al., 1992; Calvo-Cases and Harvey, 1996; Faulkner, 2013; Kasanin- Grubin, 2013; Moreno-de las Heras and Gallart, 2016).

Extreme rainfalls events are generally related to gully erosion and badlands formation in sub-humid and humid terrains, though the process is difficult to understand in the field (Grove andRackham, 2001; Vanwalleghem et al., 2005; Chiverrell et al., 2007; Pandey et al., 2021). However,extreme rainfall events as a causative factor of badlands initiation are controversial. Rather gully formation is merely controlled by land-use change (vegetation changes) in sub-humid areas (Harvey, 1992). Prosser and Soufi (1998) have suggested that the erosion rate is considerably lower under the canopy of native species. In humid regions, extreme rainfall events can trigger shallow soil slips very frequently, giving rise to debris flow and gully initiation (Rice and Foggin,1971).

Anthropogenic activities can temper the acute balance of the ecosystem and result in landdegradation, which may very frequently be accompanied by intensive erosion (Hooke et al., 2012).By modifying the drainage pattern, surface runoff reduces and gets concentrated into ditches, which can further develop as rills or gully (Gallart, 1992).

Overgrazing is one of the most common anthropogenic controls of land degradation. It directly influences soil erosion but has control over multiple related events like modification of runoff in the catchment area, alters hydrograph shapes, etc. (Brown, 1972). Ill vegetation covers also hamper the infiltration rate of the soil and causes land degradation (Zhou et al., 2010; Vetter and Bond, 2012; Carmona et al., 2013). Overgrazing can increase 30-40% more runoff and henceheavy sediment yield (Lusby, 1970). Intensive overgrazing acutely affects the ecosystem, especially; it badly hits on the plateau regions, which have a slope. Butzer (1971) has studied the relationship in the Orange and Vaal River basin in Namibia and South Africa. In his study, he noticed that due to the overgrazing and the burning of degraded grasslands, soil stripping and gullycutting action were extensively increased after 1880.

There are four main badlands hot spots found in India viz. Yamuna-Chambal ravine zone,Gujrat ravine zone, Chhota Nagpur ravine zone and western Himalayan foothills. All these four regions have a unique perspective of erosion and soil loss. But there is no documentation on the initiation of Indian badlands, though it is estimated pre-Mughal period (before the 15th Century). Furthermore, the investigation work in these four badlands is very less. Most of the work was carried out in the Chambal sector of the Yamuna-Chambal ravine zone. In the mid of nineteenth century mass migration of people and their livestocks took place due to spreading of badlands intootherwise fertile lands of the Yamuna-Chambal area (Tignath et al., 2005).The present research is anattempt to study the forms, patterns and processes of badlands formation in and around Chitrakoottown along the bank of the Mandakini River, which is the southernmost tributary of the Yamuna River system and thus this badlands system is an extended part of the Yamuna-Chambal ravine zone.

1.3 Research Objectives

Since most of the population of the study area is primarily associated with agriculture, it can be said that the gully erosion must have strongly impacted the socio-economy of the region. The erosional processes involved in badland formation have depleted the nutrient content of the soils and lowered the groundwater table of the region. Therefore, the present work aims to present a comprehensive study on identifying badlands sites, the morphology of the gully network, probablecauses and impact of badlands initiation and formation and the reclamation for the restoration of the ecosystem, with the following objectives.

I. To determine the morphometric parameters of the badlands affected sub-watersheds of the study area.
II. To determine the morphotectonic signatures of the neotectonic control on the badland formation.
III. To characterise interdependence and mutual impact of the physico-chemical properties of the soils and the badland processes.
IV. To portray the spatiotemporal analysis of the forms and patterns of the badlands.
V. To propose an Eco - restoration plan for the area.

1.4 The Benefit to the Society

The study area has a historical importance and is a significant pilgrimage site for Hindus which has a potential to be developed as a major tourism site as well as productive agro-industrial zone leading the population to sound economic condition. The area being affected by the badlands andunderdeveloped tourism conditions, has not allowed any economic growth of the people of this region. The encroachment of the lands in the study area by badland conditions has downgraded the soil properties and fertility to a great

extent limiting agricultural productions and reducing cultivable area. The in-depth knowledge of the badlands process can help to generate indices about an erosion prone terrain, which would further help in the monitoring, assessment and reclamationof the existing and emerging badlands for the benefit and growth of the society.