Chapter-9

9. Eco-restoration of the Badlands

9.1 Introduction

a) Problems of the Developing country: The problem in developing countries is often related to immediate issues of economic concern and they often leave the long-term processes of non- fertile lands especially badlands for these lands have extremely rugged topography and heavysoil losses which need big long-term programmes and sizable funds directed towards their development, eco-restoration and regeneration. Same time developed countries are engaged ininfrastructure development for industrialization and convenient transportation enhancement. Thus, other priorities with such countries leave little funds towards badlands ecosystem restoration, and therefore only such programmes can succeed which involve public interest andparticipation and is based on a multipurpose goal with several productive or semi productive components. Development activities with public engagement may involve following objectives:

   Public Participation—financial interest: agriculture and aquaculture, forestry based industries such as Bamboo forming and bamboo based industries.

   Rehabilitation watershed: New Villages, farms, fruit gardens, diaries and water resources.Displacement and resettlement of population

   Tourism: Pilgrim centre and Recreation and cultural

b) However, there are several real challenges regarding the eco restoration in the badlands. Theselimiting factors, which are actually the outcome of the present study, need to be thoroughly considered before any development programme and assignment may be designed and undertaken. These factors are as given below:

Physical characteristics of soils

Low Liquid limit: Running/flowing: Drip type/ variation

modePiping

High Bulk density: limits vegetation

Hydrogeomorphic limitation: Drainage frequency, multifractal

organization Chemical/organic: low soil organic matter.

The interdependence and influence of the various components of the badland system isillustrated in the Figure 9.1

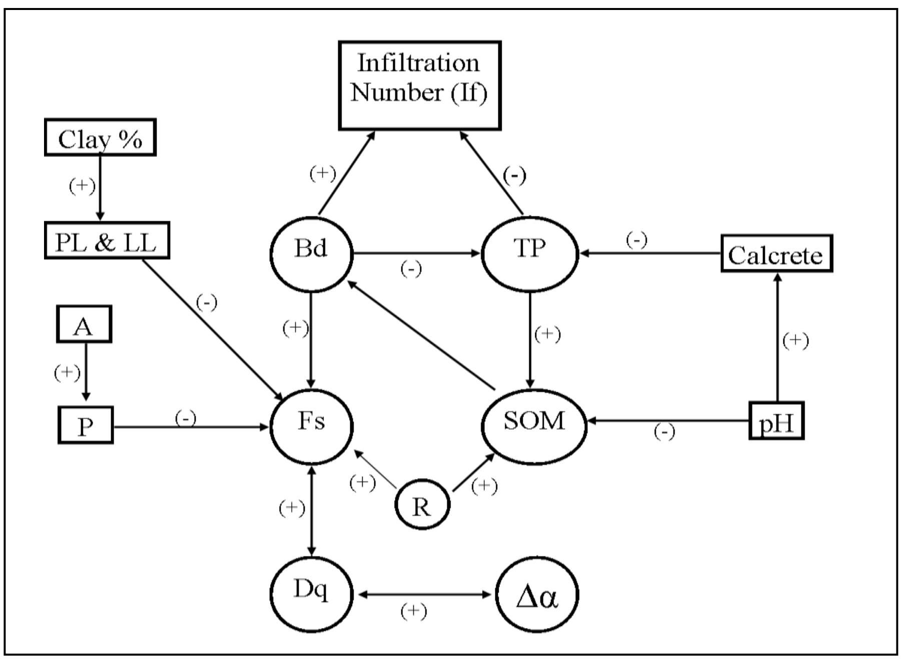

Figure 9. 1 Interdependence and influence of the various components of the badland system

Abbreviation: A- Area of the watershed; P- Perimeter of the watershed; Fs- Drainage frequency; R- Rainfall; Bd- Bulk density; TP- Total porosity; PL- Plastic limit; LL- Liquid limit; SOM- Soil OrganicMatter; Dq- Generalised dimension**;** Δα- Change in Holder’s exponent

c) Fortunately, for low relief badlands, such as the one in the present case study, there are certain advantages in comparison to those badlands which have high relief as in the Yamuna-ChambalBadlands of north India.

Advantages are as:

Low relief variations in badland zone: Reshaping of gullies is easy

Scarp retreat mechanism of gully regression into lands: sealing is

possible Populated area, agriculture based. Availability of interested

parties and labour.

Scope for more than one type of tourism Beautiful natural setting. Already a

pilgrimageplace.

Perennial river.

9.2 Systems Approach for Restoration

To maintain the reclamation process, sustainable holistic approaches are required, which cover physical, chemical and biological health of the soil. Because land reclamation is a slow and steady process, reclamation approaches should be self-sustainable, with the least alteration with the nativeecosystem (Lichtfouse et al., 2009). The aim of the reclamation approaches should enhance the degraded chemical property of the soil like, soil organic matter (SOM) and pH, followed by moisture content of the soil. Vegetation growth improves with the relatively higher moisture content, which enhances microbial growth, soil organic matter content, nutrient content and helpsto reduce pH to neutrality. Likewise, it can reverse or stop the positive feedback loop of land degradation.

Engineering structures can play a greater role in holding the flow of water and preservation of sediments; whereas, the vegetation measures will support and provide stability and sustainability to reclamation. Engineering approaches like, construction of check-dams is meant for medium and large-scale gully. The role of check-dams in these scenarios is to check the waterflow so that loss fines sediments will be minimal and improve the groundwater table. In the operation of this process, once the moisture of the soil maintains slowly but steadily, microbial activity in the soil may increase and the carbon pool of the soil will revive.

The study area has a long history of channel erosion in the form of rills and gully. There isno official record of initiation of the gully in the region. It is estimated that the onset of the gully in this part of Central India was the Pre-Mughal era (Haigh, 1984). The study area has diverse gully topography. On the basis of the size, gullies of the area can be classified as (i) small (<1m depth), (ii) medium (1-5m depth) and (iii) large gully (>5m depth). The study area has a V-shaped valley and a trapezoidal gully; and a continuous branched-shaped gully. These forms of gully create a parallel pattern of gully network. Moreover, it can be said that the area is highly degraded and needs reclamation support. The Gullies extend into interior lands through scarp retreat (Figure 4.3b). Gullies have various dimensions in this terrain; the maximum width and depth of the gullyhave been observed 29m and 10m, respectively, nearly reaching channel dimensions or ravineous form (Figure 4.4). Generally, the gully slope is vertical in less wide gullies whereas for wider gullies the slopes vary in slopes angles but are generally above 60 degree. The local farmers have adopted the most popular land reclamation techniques i.e. the unplanned gully reshaping and fillingmethod. Under this technique, gully mounds were levelled and the displaced material filled the channel to obtain as nearly level ground as possible. Local farmers use this freshly levelled land for the plantation of winter crops (Ravi crop) like mustard (brassica rapa) and pigeon pea (cajanus cajan), which require less amount of water. But, the crop yield remains low in such recently levelled areas and erosional activities continue to happen. Therefore, the reclamation plan should be carefully executed, so that a productive ecosystem may survive and flourish in the future. A self-sustainable reclamation can certainly give more agricultural land with higher yield to the farmers and augment a prosperous local economy.

This chapter discusses possible reclamation approaches to restore the study area based onthe holistic knowledge of the watershed, regional active tectonics, soil's physico-chemical properties, paleo-climate and micro morphology (Figure 9.2).

9.3 Vegetational and biological approaches

Vegetation strengthens the soil health condition by holding the soil structure and root system and encouraging vertical water movement to the soil (Preston and Crozier, 1999). Reclamationapproaches by vegetational measures utilize grass, shrubs and plants to slow down rain's kinetic energy and runoff (Zuazo and Pleguezuelo, 2008; Duan et al., 2016). These practices are basicallyadopted in the region affected by small to medium sized gullies.

Grasses provide an envelope of protection from rain shower and also offer a strong grip from its fibrous root system (Zaharia et al., 2008). Grasses along with shrubs are the most suitablecombination in the reclamation of less stable slopes (Denisa et al., 2013). Since shrubs are tiny insize compared to plants and their roots are moderate, it provides stability without disturbing the slope stability of the area (Bors-Oprişa, 2011). Like grass and shrubs, plants are also significant for preventing soil erosion. According to Farley et al. (2005), annual runoff reduces considerably (about 31-44%) when grassland and shrub land are converted into plantation forests. Its effect is enhanced significantly with the plantation age; i.e., the older the plantation, the lesser the erosion.

According to Simon and Collison (2002), plant roots increased bank safety factors by an average of 39% for woody species and 70% for grasses and shrubs. Nonetheless, plant community,along with grass and shrubs, can effectively prevent soil erosion. The volumetric reduction in run-off results in the reduction of soil erosion or sediment loss.

In the reclamation of small and medium size gullies, vegetational plans are very effective.In this process, gully or rills can be reshaped (reduction of slope of the sidewall) and suitable species of grasses are grown. The channels are converted into grassed waterways as practiced in sod flumes and sod strip checks (Agr. Handbook No. 61, USDA. SCS).

This worker noticed during the field investigation that the mounds of gully sites have indigenous grass, shrubs and plant species (Figure 8.2), listed on Appendix 8.1, which can play asignificant role when also grown in the gullies and channels in preventing the soil erosion process.

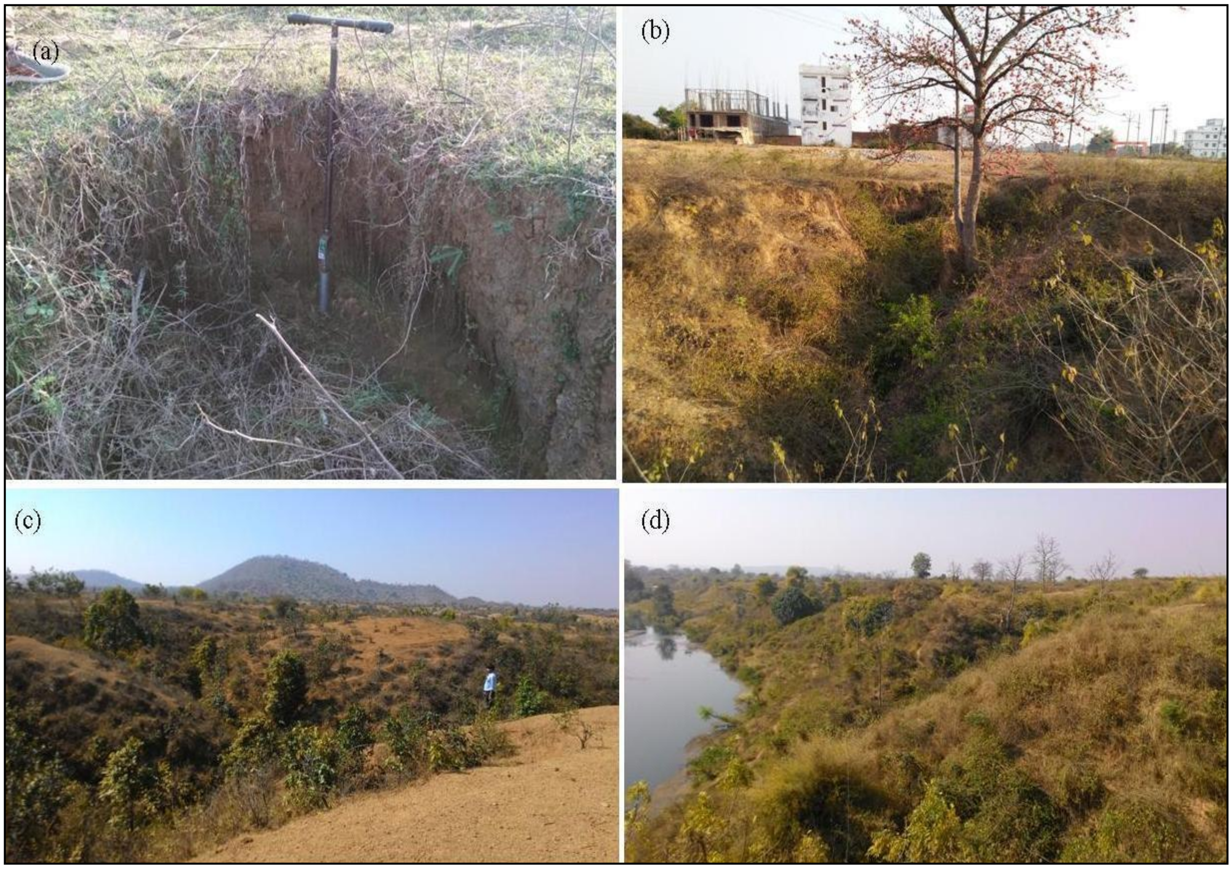

Figure 9. 2 Field photographs showing (a) and (b) Scarp-headed gully, native vegetation, lackingvegetational diversity in terms of variety of plants and trees. (c) and (d) Tall trees with huge canopy are completely missing in most of the badlands in the study area.

9.4 Engineering Approaches

Engineering structures provide mechanical barriers to check the runoff and allow siltation. In thisapproach various retention walls/dykes are constructed across the longitudinal cross-section of anephemeral gully, depending upon its dimensions.

Depending on the durability, there are basically two types of contentment structures, Temporary Gully Contentment Structure (TGCS) and Permanent gully contentment structure (PGCS). Temporary contentment structures are constructed across the small or medium sized gully. The materials used to build these kinds of temporary structures are raw and locally available.However, the durability of TGCS is relatively low (3-8 years), whereas, PGCS structures are builtacross large gullies (>5m deep and >20ha catchment area). These kinds of structures are relatively massive, costly and requires large amount of building materials for the construction.

Some of the popular TGCS are: Gully reshaping and filling, woven-wire check-dams, brush check-dams, loose rock check-dams, plank or slab check-dams, log check-dams, boulder check-dams (Agr. Handbook No. 61, USDA. SCS). Drop spillway, Chute spillway, Drop-inlet spillway structures and permanent earthen check dams are some popular permanent gully contentment structures (Michael and Ojha, 1966).

9.5 Reclamation plan

Since the soil of the area has long been degraded, regaining back the land neutrality is a time- consuming process. Moreover, the soil of the study area has a high pH, a predominance of silt, lowplastic and liquid limit and organic matter content that have rendered the soil vulnerable to erosion. Consequently, due to prolonged erosion, the nutrient value of the soil has been reduced, bulk density of the area is also considerably high, which restricts plant root growth.

So, in order to achieve the land neutrality, the most significant priority while planning thereclamation works in the study area is to reduce the runoff and enhance the moisture and soil organic matter. The organic matter gives a new life to the soil, as it binds the grain and provides nutrients to it, altogether, it enhances soil structure and improves soil health. In order to give strength in the healing process of the soil, several check dams should be constructed along with vegetation support. This will enhance the water table of the area and retain the soil moisture for a longer duration in the year. These tiny, gradual but effective techniques can help achieve land neutrality target and revert the erosive cycle.

In order to control headward erosion and further expansion of large gully, check-dams arethe only simple possible solution. To restore a single gully system, multiple check-dams should bebuilt across the gully; the type of check-dam depends on the catchment's hydrological condition, catchment area, soil type and ground stability and raw material availability. Since gullies are ephemeral and there is no such instrument that measures the runoff and flows conditions of the gully channel, so we cannot suggest an accurate design of the check-dam with pinpoint accuracy in the study area, but the type and location of the check-dams can be predicted on the basis of gullydimensions and catchment area. There are total of 104 locations which are identified for various check-dam constructions in the study area (Figure 8.3), out of which 60 rock-woven wire check- dams, 20 loose check-dams, ten boulders check-dams, 8 log check-dams, four permanent and twodrop spillway check dams. Permanent structures like drop spillway and permanent earthen check-dams are suggested to construct at the mouth of large gully systems with deeper valleys (>5m). Potential sites near Hanuman Dhara and Kamath Giri are identified for these two enduring structures. Apart from these, a few sites are also acknowledged for the drop spillway structure in the central and south-eastern region of the watershed, which has medium-sized gullies. Boulder, loose, log and rock-woven wire check-dams are suggested to be constructed across small to medium-sized branched gullies. The scarp heads of the gullies of the area may also be plugged with small retaining/face lining structures to check headward erosion and retreat of the scarps.

The gully reshaping and filling method are very popular in the region and farmers are foundit easy, quick and cost effective. Therefore, reshaping should be done in the post-monsoon period,small bunds should be made based on the slope of the field and grass and shrub varieties should be planted for at least three years so that some organic matter can develop the soil. The mulchingand mixing bio-fertilizer in the soil is also a brilliant idea that reduces the healing time.

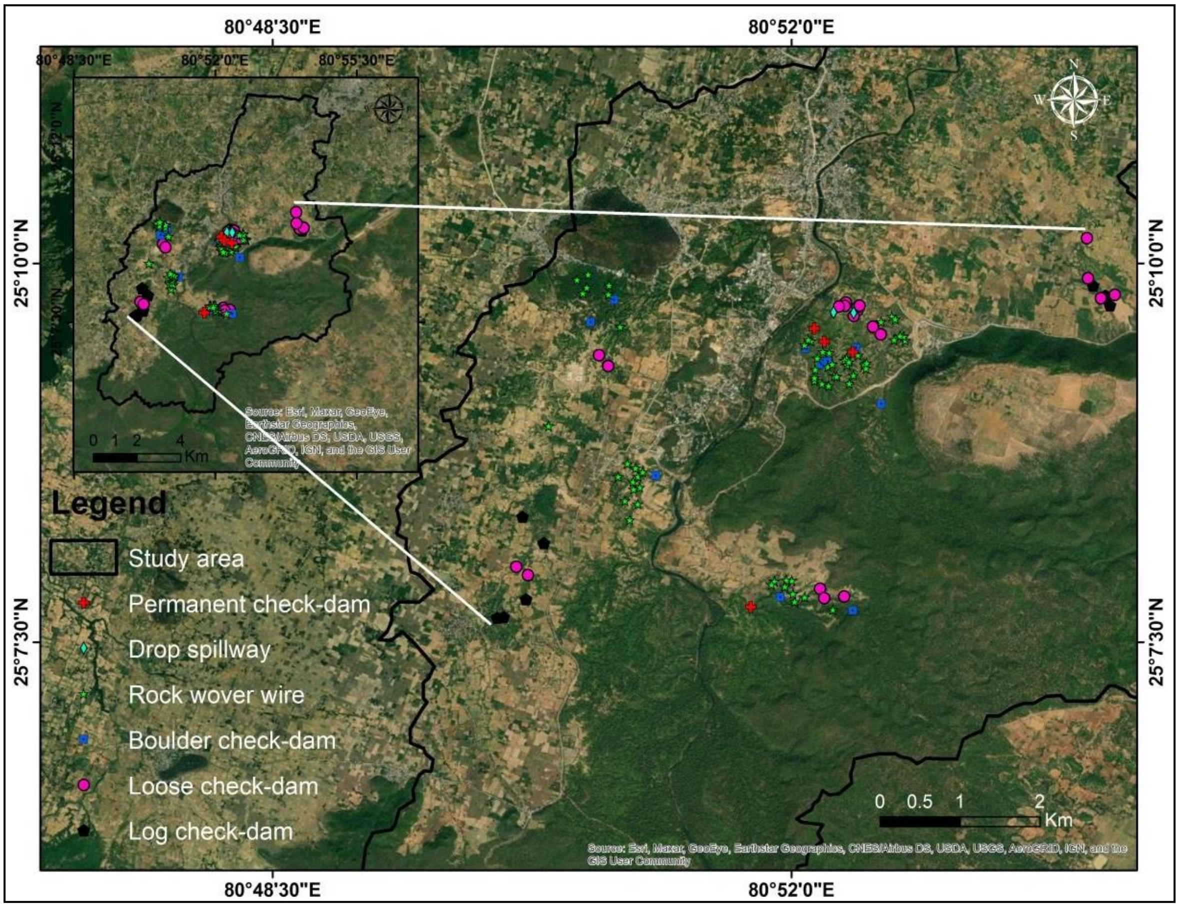

Figure 9. 3 Identified locations for the constructions of various check-dams in the study area.

9.6 Geotourism

The study area has picturesque setting of overlooking escarpments, rising high up in the east and south and isolated hills rising from badlands general levels. The high cliffs, hills, forests and incised valleys can make the area a place of choice for various types of attractive tourism sites in the future. It is an ideal section for studying the formations of the Rewa group of the Vindhyan Supergroup (1650 Ma to 650 Ma) of Proterozoic times. Also, erosional forms like Buttes and Mesas along with scarp sections and slope processes make the area a perfect site for geo tourism.

Apart from Geo tourism, the site is related to religious importance to all Hindus. It is said, as widely written in the epics of Ramayana that Lord Rama, his consort Sita and younger brother Lakshamana stayed here for about eleven or twelve years of their fourteen years of exile from theAyodhya (UP). Over a million religious people visit the place in every year on various festivals and the full moon nights every month. This place certainly is an important place of pilgrimage andcan therefore be made further attractive by developing other kind of recreational places. There arenatural opportunities available for developing other activities and tourism:

Both Hanuman Dhara and Kamath Giri have potential for establishing ropeways up to the peaks. These sites can be developed for adventurous sports like paragliding, abseiling, bungee jumping, rope walk, rope gliding, etc.

There can be a full range of herbal garden and fruit bearing trees of forests which were indigenous to the area before deforestation. This can give a big impetus to otherwise staggering economic conditions of the local people already facing the problems of badlands.

When there would be hope for various tourism and farming and agro-industrial development through eco-restoration and resources local population would certainly partake in the rejuvenatingactivities.

Therefore, the holistic plan may be undertaken and local people may be led to resolve for the overall development programme, of course, under the guidance of experts and funding supports from the government. The various components will make the following system:

1. Government-people cooperation programme and Body
2. Initial reshaping of lands and low-cost operations on the places for tourist activities.
3. Water Resources development and management system.
4. Herbal and fruit gardens. Afforestation.
5. Construction of soil and water conservation structures, natural gallery and sports andtraining centers such as Rock climbing etc.
6. Aqua culture Gullies development and water sports.
7. Agro-industries: Wild fruit processing, Herbal industries, Bamboo Industries etc.

These components functioning in a cooperative manner can change the state of affairs in the locality. Economic growth and general development of the area can be assured in the otherwise problematic and non-productive badlands.

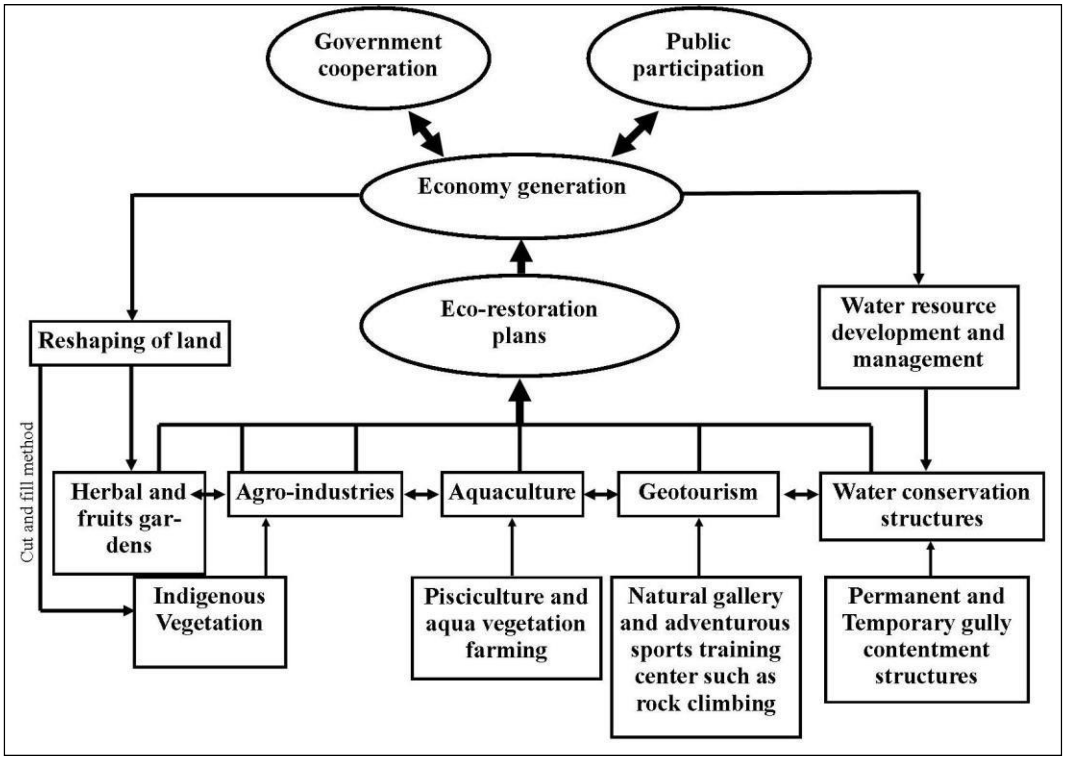

Figure 9. 4 Eco-restoration plan of the badlands area