AGROFORESTRY INTERVENTIONS FOR REHABILITATION OF RAVINE LANDS IN INDIA

DHIRAJ KUMAR[1]*, S B CHAVAN[2], NISHANT K SINHA[1], JITENDRA KUMAR[1], VIJAYSINHA D KAKADE[2]

[1]ICAR- Indian Institute of Soil Science, Bhopal, Madhya Pradesh
[2]School of Soil Stress Management, ICAR-National Institute of Abiotic Stress Management, Baramati, Maharashtra
*Corresponding author, E-mail: Dhiraj.Kumar@icar.gov.in

RAVINES (Bihads), one of the most vulnerable ecosystems that harbour complex edaphic, topographic, and climatic features with unstable socio-economic scenarios, represents extreme land degradation by runoff water. As reclamation and management of these landforms are extremely challenging they are being considered as "cancer of the land" (Figure 1). Ravines are characterized by high undulated topography, unfavourable climate, low soil fertility, high biotic pressure, uneconomical natural vegetation, and absence of productive land for cultivation. In India, the average annual rainfall across major ravines regions varies significantly. It differs from 800 mm in the Chambal-Yamuna zone to 1500 mm in Chota Nagpur Plateau (Sharma, 1980). The major area of the ravine in India is the Yamuna-Chambal ravine that extends from Madhya Pradesh through Rajasthan and Uttar Pradesh.

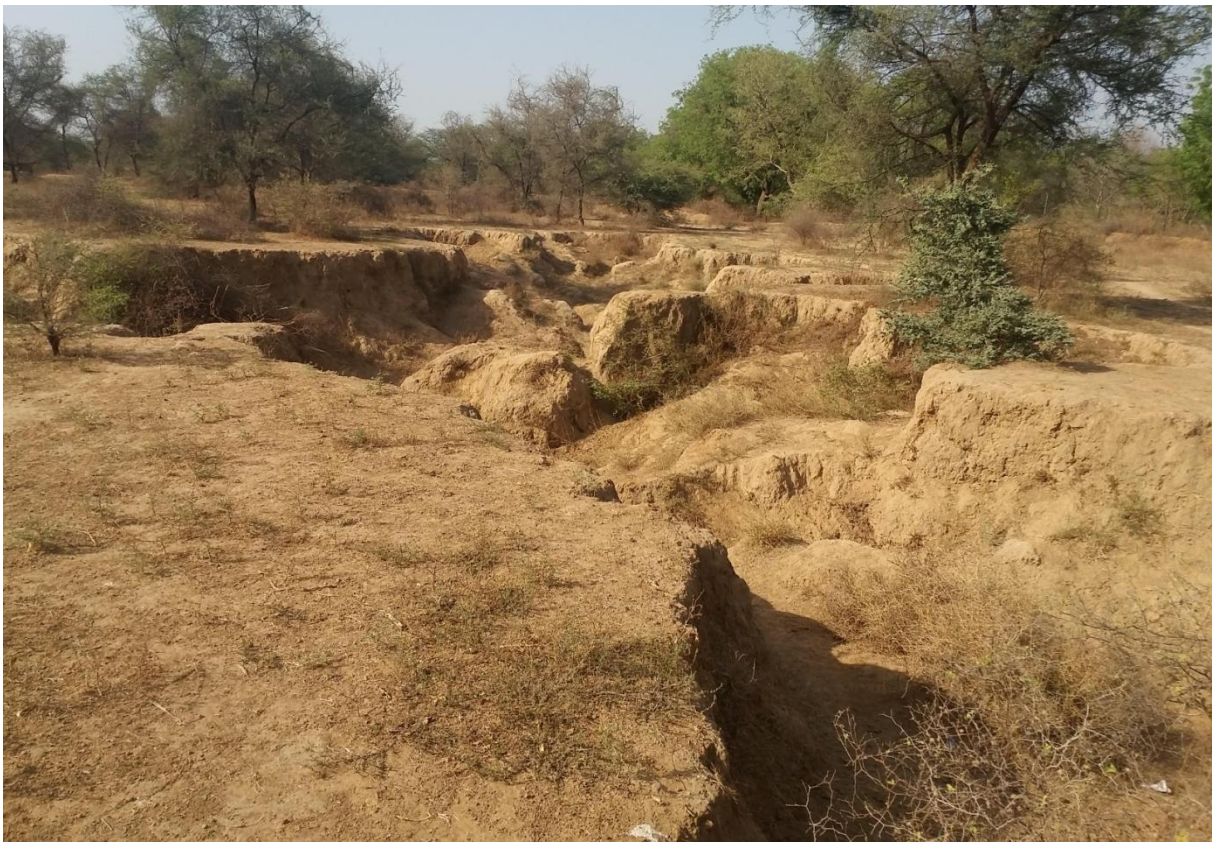

Figure 1: A view of ravines present in the Vasad region of Gujarat state of India

CLASSIFICATION OF RAVINES BASED ON RECLAMABILITY

Bali and Karale (1977) classified ravines into five main classes based on their depth, width, hardpan or rock, bed slope mainly on inter-gully land, and groundwater.

Class I: Very good ravine land that can be reclaimed readily with minor reclamation measures. These include shallow ravines having a width of 30 m or more and no calcareous layer within 1.5 m depth.

Class II: Good ravine land that can be reclaimed with minor operations requiring more dozing work than Class I. Bed slope may vary from 5% to 10%.

Class III: Moderate ravine land with medium depth. The bed slope varies from 10% to 15%, and the presence of calcium carbonate hardpan or bedrock within 0.5–1.0 m depth from the surface.

Class IV: Poor land with medium to deep gullies of narrow width. The hardpan or bedrock can be found within 0.5 m depth, very costly to reclaim, or not suitable for cultivation after reclamation.

Class V: ravine land unsuitable for reclamation and can be developed for forestry/grassland.

RECLAMATION OF RAVINES LANDS THROUGH AGROFORESTRY

Ravines with narrow and marginal to moderate gullies could be successfully utilized for growing agricultural crops. However, integrating perennial trees, horticultural fruit trees, forests, and grasses would be a good option for managing land with deep and wide gullies or non-arable lands. The incorporation of fruit and forest species will help to create employment and income-generation and improve ecological balance, reducing regional inequalities and poverty. Therefore, agroforestry is a potential land-use management tool for ravines that can support livelihood improvement providing food, fruit, fodder, fertilizers, firewood etc. and indirectly improves soil health (Chavan *et al*., 2016).

Fruit trees like aonla (*Phyllanthus emblica*), lemon (*Citrus limon*), ber (*Zizyphus mauritiana*), mango (*Mangifera indica*), sharifa (*Annona squamosa*), pomegranate (*Punica granatum*), imli (*Tamarindus indica*), karonda (*Carissa carandas*) etc. can be successfully grown under agri-horti system in ravine habitats. In ravine areas, practice of soil conservation measures such as staggered trenches, small check dams, gabions structures, drop structures, wattling, peripheral bunds can be promoted for better moisture conservation, check erosion, and reduce soil fertility deterioration. These structures further help in arresting the expansion of gullies.

Shrubs and grasses like *Agave americana*, *Grewia asiatica*, *Lantana camara*, *Clerodendrum*, *Ziziphus nummularia*, *Cenchrus ciliaris*, *Brachiaria*, *Dichanthium annulatum*, *Pedalium murex*, *Cleome spp*. etc. can be grown successfully for live fence maintenance. Tree species like *Acacia nilotica, Gmelina arboria, Drendocalamus strictus, Prosopis juliflora, Albizia amara, Albizia lebbeck, Acacia tortilis, Kigelia pinnata, Morus alba, Bauhinia purpurea, Acacia catechu, Acacia senegal, Ailanthus excelsa, Panicum antidotale, Eucalyptus tereticornis* etc. are also ideal for the revival of ravine ecology.

Since growing crops is almost difficult in ravines local people struggle to arrange fuelwood and fodder for their livestock. Unfortunately, the local economy in ravines depends upon livestock (Figure 2). Hence, reclamation of ravine lands through agroforestry generates an opportunity to refurbish the lands for growing crops and fodder. A model developed by ICAR-IISWC Regional Centre Vasad intercropped dragon fruit with *Melia dubia* for reclamation of ravenous lands (Figure 3). In Yamuna ravines, the agroforestry system is another example where *Cenchrus ciliaris* is intercropped with *Acacia nilotica* for fuelwood and fodder requirements. After 15 years of plantation, *Acacia nilotica* produced fuel wood biomass of 34.4 Mg ha^{-1}, fodder biomass of 3.8 Mg $ha^{-1,}$ and Cenchurus biomass 1.52 Mg ha^{-1} $year^{-1}$ (Prajapati *et al*.,1993).

REHABILITATION OF RAVINES THROUGH THE ESTABLISHMENT OF BAMBOO PLANTATIONS

The rehabilitation of ravine lands through vegetation serves the purpose of livelihood support and conserves natural resources and enhances carbon sequestration in the long term. Moreover, the vegetative covers help to enrich flora and fauna and reduce the impact of climate variability with sustained productivity.

Growing bamboo trees in ravines can be a profitable option to revive ravines. Bamboo is one of the fastest-growing plants and could be very effectively grown in homesteads, riverbanks, along embankments, along drainage channels, field bunds, marginal lands, etc. India exploits only about one-tenth of its potential of bamboo production. Through its vigorously growing rhizome-root system and leaf litter accumulation, bamboo conserves soil moisture, prevents soil erosion, helps in carbon accumulation, reinforcement of embankments, channels, etc.

There are around 130 species of bamboo but, hardly ten species viz., *Bambusa tulda, B. balcooa, B. affinis, B. arundinacea, B. strita, Dendrocalamus asper, D. strictus, D. hamiltoni, Oxytenanthera stocksii, and O. Travancorica*are being commercially exploited. Among these, *D. strictus* has been found quite promising for rehabilitating ravine lands (Figure 4). The biological characteristics of bamboo make it a very fit and unique species for the management of ravine lands to prevent soil erosion and improve livelihood security. Bamboo also serves as a viable option for employment generation and remunerative returns through additional returns (Table 1).

Table 1: Yield and net income expected from bamboo plantations in Chambal ravines

Years	**Yield** *(no. of bamboo poles/ha)*	**Net Income** *(₹/ha)*
VII	1200	28950
VIII to X	1200	29400
XI year on wards	1600	41400

(Source: Pande *et al*. 2012)

Figure 2: Lopping of trees in ravines for fodder requirement at Datiya, Madhya Pradesh

Figure 3. Rehabilitation of ravines through dragonfruit+Melia dubia agroforestry at ICAR-IISWC, RC, Vasad (Gujarat)

Figure 4: Bamboo plantations for reclamation of ravine lands in Banda district of Uttar Pradesh

CONCLUSION

Ravine land management and its rehabilitation are quite necessary at times when the existence of this unique ecology is in danger due to overexploitation and anthropogenic pressure. Most of the gullied and ravine lands are not inferior as per their capabilities but were left abandoned due to several other reasons. Thus, the rehabilitation of ravines mainly with deep and narrow gullies and non-arable ones through vegetative means is the need of the hour. The vegetative barriers or plantations conserve soil moisture and protect soil erosion through their deep-rooted system. Tree plantations along the embankments and ravine ecologies serve the very purpose of bed stabilization; controls soil erosion, reduce runoff volume, and vigorous vegetative cover. It will minimize ravine expansion, enhance the floral and faunal biodiversity, and benefit the local community through income and employment.

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