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MAJOR HURDLES TO THE REGENERATION IN DRY TROPICAL FOREST OF RAJASTHAN

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ABSTRACT

Forests are the most valued renewable resources and play a vital role in local and regional communities' economic and social well-being. In recent years, the loss of forest cover has emerged as a major problem, the major reason being deforestation. The contribution of forests to sustaining life on earth is dependent on both natural regeneration and human management. Natural regeneration in many places is hindered by various climatic, edaphic, and biotic factors. In Rajasthan, the long dry season resulting in low soil moisture and low precipitation is a major climatic reason for low regeneration in forests. Amongst biotic factors, grazing is the most hazardous factor that eliminates seedlings and saplings in regenerating forests. Cattle-rearing tribes in the western parts of Rajasthan cause trouble during the regeneration stages of the natural forests. Controlled and rotational grazing with restricted grazing during the regeneration stage may help to protect the seedlings/ saplings during early regeneration. It is suggested that assisted regeneration and implementation of restoration techniques in later stages are necessary to restore forests to their natural pre-disturbance status.

KEY WORDS : Forest, Regeneration, Grazing

INTRODUCTION

Forests cover 31 % of the global land area out of which more than one-third is naturally regenerating forests with native species which indicates that ecological processes of such forests are not significantly disturbed by anthropogenic activities. Forests are becoming more and more valued primarily for the varied biological services they offer to nearby communities (Martín-Forés *et al.*, 2020) not just for the lucrative wood production business but their role in climate change mitigation also (Gamfeldt *et al.*, 2013; Bastin *et al.*, 2019). But in recent years, loss of forest cover worldwide has emerged as a major cause of climate change. Global Forest Resources Assessment report estimated that the world's forest area decreased by approximately 3% between 1990 and 2015 (FAO, 2018). According to FAO Global Forest Resource Assessment estimates, some 420 million hectares of forest have been lost between 1990-2020, although the rate of deforestation has decreased over the past three decades from 16 million ha/year in the 1990s to 10 million ha/year in 2020 (FAO, 2020) and a global net loss of forests of 4.7 million ha/year between 2010 and 2020 (FAO, 2020).The area of primary forest worldwide has decreased by over 80 million hectares since 1990, however, the regeneration of forests offset these losses to some extent. The UN FAO 1990 report also estimated that deforestation in developing countries of tropical regions was 154 million hectares. During 2001-2023, the annual rate of tree cover loss was nearly doubled in tropical countries, increasing from 6.7 million hectares to 12.1 million hectares.

A significant portion of about 38.2%of India's total forest cover, is made up of tropical dry forests (MoEF, 1999). In 2010, India had 31.3 million

([1]Professor, [2]Assistant Professor, [3]Research Scholar) hectares of natural forest, extending over 11% of its land area. According to the Global Forest Watch data, from 2001 to 2023, India lost 2.33 MHa of tree cover, equivalent to a 6.0% decrease in tree cover, out of which 0.62% of tree cover loss occurred in areas where the dominant drivers of loss were prevalent which resulted in deforestation. India has seen the highest rise in deforestation in the last 30 years with average deforestation of 668,400 hectares, with a significant increase between 2015 and 2020. The tree cover loss since 2000 is equivalent to 1.20 Gt of CO_2 emissions. In 2023 alone, India lost 134 kha of natural forest, equivalent to 81.9 Mt of CO_2 emissions. In the tropics, vegetation communities of tropical dry forests comprise some of the most endangered ecosystems (Hoekstra *et al.*, 2005). Rajasthan is the largest state, occupying an area of about 342,239 Km^2 and covering 10.41% of the geographical area in India. Being in arid and semi-arid part of India, the major proportion of forest cover in Rajasthan is occupied by dry deciduous forests (79%) and thorn forests (16%) (Reddy *et al.*, 2011).

Seasonal rainfall characterizes tropical dry forests, and the annual cycle includes many months of extreme drought (Mooney *et al.*, 1995). Tropical dry forests are the most endangered of the main types of tropical forests; around 90% of these forests are vulnerable to various hazards, most of which are brought on by human activity (Miles *et al.*, 2006). The tropics accounted for roughly 97% of all global deforestation this century, even though just half of the loss of tree cover worldwide happened there (related to urbanization, agriculture, and other commodity production) (Myers, 2023). Between 2001 and 2023, the yearly loss rate of tropical tree cover doubled, from 6.7 million hectares to 12.1 million hectares. Often regarded as one of the most species-rich terrestrial ecosystems, tropical forests provide a range of natural resources that support local communities' way of life (Kumar *et al.*, 2006). Tropical forests store 25 % of the terrestrial above- and below-ground carbon (Bonan, 2008). Thus, with the declining global forest cover at an alarming rate, forest restoration is necessary and the regeneration of forest trees is often a key component of restoration.

Around the world, efforts have been made in the past ten years to restore degraded forests. The UN-REDD+ program is focused on encouraging forest restoration by creating a market value for Carbon stored therein (Jacobs *et al.*, 2015). In recent years the higher cost of restoration using site preparation (Crouzeilles *et al.*, 2017; Meli *et al.*, 2017; Reid *et al.*, 2018), and plantation of tree species and the results of restoration projects have forced policymakers to switch to low-cost alternatives using natural regeneration involving native tree species.

Why natural regeneration is better/ Regeneration is important for the good health of the forest: Over the last two decades, researchers have started to suggest that forest regeneration should be seen as an opportunity for recovering forest biodiversity (Navarro and Pereira 2012, Merckx and Pereira 2015). The high economic costs of large-scale tree plantation programs, as well as their eventual social and environmental impacts (Bullock *et al.*, 2011; Fagan *et al.*, 2020; Holl and Brancalion, 2020; Lamb *et al.*, 2005) render passive forest restoration as an indispensable management tool in many regions of the world. In addition, the ecological success of restoration actions is commonly higher with approaches based on natural forest regeneration than those using active restoration (Crouzeilles *et al.*, 2017). Despite all of these shown benefits, we still lack a thorough understanding of how to effectively utilize tree populations' and communities' natural regeneration potential to promote forest restoration (Hampe *et al.*, 2020).

Status of forest in Rajasthan: Rajasthan is the largest state in India, occupying an area of about 11 % of total area of India. Having rich flora and fauna, the natural vegetation of Rajasthan is classified as Northern Desert Thorn Forest (Champion, 1936; Champion and Seth 1968). According to the Forest Survey of India 2009 report, the forest covers only about 11 % of the geographical area including roughly 7 % of the depleted and denuded forests (FSI, 2009). The Aravalli hills in the state mainly represent tropical dry deciduous forest which is one of the world's most threatened ecosystems (Gentry, 1992). However, the dry deciduous forest is gradually converted to scrub and savanna (Sagar & Singh, 2005). Various studies state that the tropical dry deciduous forest was dominated by a few species only as also reported for the tropical forest in Udaipur (Kumar *et al.*, 2011). Disturbance and degradation are one of the causes of this condition. In many cases, the Dominance-diversity curve shows that generally, one or two species in the vegetation exploited major resources of forests (Sultana *et al.*, 2014).

What are the causes of degradation of forest in Rajasthan: From 2000-2020 forest cover in Rajasthan was reduced by 384.81Km^2 which is about 24.48% (Singh *et al.*, 2024). Among various other reasons, drought and famine resulting deforestation in the Ranthambhore National Park (Singh, 2003). Due to the severe climatic condition mentioned above, the forest & tree cover of Rajasthan State is only 7.11% (forest cover is 4.69%, and tree cover is 2.42% respectively), which is far below the national average of 23.4%, and the open forest cover out of the total forest is as high as 71.8 %. (Project Report, Dept of Forest, Govt of Raj., 2024). However, the main reason of forest degradation is unsustainable and illegal logging.

Need for restoration through natural regeneration: Conservation of natural forests depends on a sound understanding of the forest ecosystem (Sussman & Rakotozafy 1994). This includes understanding native plant species distribution, structural parameters, and natural regeneration. Understanding species diversity and distribution patterns is important for helping managers evaluate the complexity and resources of these forests (Kumar *et al.*, 2001, 2002; Yadav and Yadav, 2005). Likewise, through studies in the past, the processes that leave long-term legacies in current forests may be identified (Johnstone *et al.*, 2016; Jõgiste *et al.*, 2017).

Natural regeneration of trees may provide a cost-effective way to restore degraded tropical dry forests, but the factors predominantly affecting natural regeneration success are poorly understood. Short-term fences had a major effect on reducing mortality but did not improve the abundance or diversity, whereas cattle grazing significantly affected the abundance of seedlings (Cueva-Ortiz *et al.*, 2020).

What are the barriers to regeneration: Studies on restoration through natural regeneration attempts worldwide have shown that knowledge about the natural regeneration potential of trees needs more practical knowledge. Many factors limit the natural regeneration of trees. A major barrier to effective active restoration is frequently a lack of regeneration material (Cernansky, 2018). The availability of propagules often limits the initial stages of forest recovery (Cramer *et al.*, 2008). In dry tropical seed banks contain low numbers of seeds and plant species (Espinosa *et al.*, 2012; Ceccon *et al.*, 2006). Thus, the low availability of seeds negatively affects the species richness and abundance in regenerating forests.

Stressful environmental conditions resulting from forest degradation are also proved as a challenge to the successful establishment of recruiting plants (Basnou *et al.*, 2016). Various climatic factors affect the natural regeneration of vegetation. In most cases, natural regeneration was most positively affected by precipitation (Khaine *et al.*, 2018) likewise, soil conditions also played an important role (Liu *et al.*, 2011). Significant processes affecting forest regeneration are carried out by ground vegetation and the soil system, which includes leaf litter (Nilsson *et al.*, 1998).

Seasonal variation of available moisture affects both mortality and recruitment in tropical dry forests. During the rainy season, a higher recruitment rate is visible whereas higher mortality is visible in the dry season (Lieberman and Li, 1992; Cabin *et al.*, 2000; Vieira and Scariot, 2006). In Rajasthan, most of the areas suffer from hyper-arid conditions that require extreme water management (Biswas and Karmegam, 2023) though the dryland ecosystem of western, northern, and southern parts encounter wetter conditions, while north-eastern, eastern, and south-eastern regions face expanded drier circumstances. In Rajasthan, prolonged dry season limits soil moisture inhibits seed germination, and causes mortality of the seedlings. Various scientists studied this seasonal mortality, showing that seedling mortality was higher in the dry season than in the rainy season (Rodriguez, 2006; Lieberman and Li, 1992).

Not only climatic factors but site-specific ecosystem complexity, density, species richness, and diversity, were also found to be the most influential factors that affect the density and diversity of natural regeneration (Khaine *et al.*, 2018). Natural regeneration involves the re-establishment of native tree species, so to know about plant species of desired properties or get propagules basic knowledge about the pre-disturbance state is necessary.

Fig. 1. Status of forests during the dry season

At the establishment phase of propagules, grazingis considered detrimental to the natural regeneration of the forest. Grazing not only interferes with smooth regeneration but exerts a negative effect on the structure of mature forests, particularly in terms of the abundance of individuals (Stern *et al.,* 2002; Cierjacks and Hensen, 2004; Schulz *et al.,* 2016). Studies show that short-term fences significantly reduced mortality but did not improve the abundance or diversity, whereas cattle grazing significantly affected the abundance of seedlings (Cueva-Ortiz *et al.,* 2020). Fencing is a very cost-intensive approach in a large forested area, low-cost strategies should be applied in such areas. This may include direct seeding of selected plant species that are more browse tolerant, using nurse trees/shrubs or by providing physical protection for the target trees. To release grazing/browsing pressure from targeted regenerating species, additional sites having local herbaceous species can be grown and maintained (Felton *et al.,* 2016). Low to moderate intensity of grazing stimulates plant growth and diversity but heavy grazing leads to vegetation retrogression (Kikoti *et al.,* 2015).

In Rajasthan, most small and marginal farmers depend on common grazing lands to meet the fodder requirements of their animals. The grazing lands (both forest and non-forest) contribute to as much as 30% of livestock forage. The hot arid zone of Rajasthan includes degraded forest land that is illegally or legally allowed for grazing (Mishra and Kumawat, 2020). Uncontrolled grazing and browsing put pressure on the already declining natural forests due to which forests become sparse and barren during the dry season. The uncontrolled grazing leaves the tree with only a crown with few leaves.

Fig. 2. Grazing in natural vegetation

Forests are usually predicted to have very low densities of pioneers and availability of propagules (Peterson and Carlson, 1996) following disturbance. The population size of seedlings and saplings determines the regeneration status of species (Khan *et al.,* 1987), a good quantity of which indicates a successful regeneration (Saxena and Singh, 1984).

Management and Recommendations: Understanding biotic and abiotic factors that affect the ecophysiology of plant establishment in a degraded site is required to overcome inherent challenges on restoration sites. The study of pre-disturbance status helps in site preparation and understanding biotic and abiotic constraints of natural or artificial regeneration and other limiting factors.

Natural forest recovery is promoted by high local resource availability including a good quantity of propagules. In many cases, regeneration is assisted or enhanced by human intervention to make the restoration of forests a success. Such intervention involves seeding, plantation of native plant species, fencing, and monitoring of survival of seedlings. Collecting, storing, and pre-treating seeds followed by cost-efficient cultivation of the seedlings in nurseries also enhance regeneration success.

Various studies show that members of the family Fabaceae are the most abundant plants in Rajasthan (Jaiswal and Dadhich 2010; Malav *et al.,* 2023). In the summer season, *A. nilotica* (L.) Willd ex Del is the most available cattle feed in Rajasthan (Wood *et al.,* 2001). *A. leucophloea* (Roxb.) Willd is capable of growing in very poor soils, which probably accounts for it being widespread in communal grazing areas (Hoeggel *et al.,* 1994). In western Rajasthan, *A. leucophloea* (Roxb.) Willd was found to constitute 75% of loppable fodder trees with shallow and rocky soils (Hoeggel *et al.,* 1994). However, the pods being toxic, (Bhadoria and Gupta, 1981; Katiyar, 1981) the species is not as popular with cattle keepers as *A. nilotica* (L.) Willd ex Del.

Efficient regeneration systems currently exist for only a few tree species, mostly for use in industrial plantations and these techniques are not always suited for restoration programs (Löf *et al.,* 2012). Consideration of local forest resource demand is also a big challenge while planning or implementing natural regeneration. The success of restoration through regeneration largely depends on the protection of plant regeneration from the usage of the plant at the seedling or juvenile stage. Many plants are used by locals at seedling stages which inhibits the availability of mature tree species. Many cattle-rearing tribes which inhabiting nearby the forest resulting in overgrazing the regenerating tree seedlings and saplings. In such overgrazed areas, the regeneration of seedlings and saplings is threatened (Bergmeier *et al.,* 2010). Goats, sheep, and camels usually trample small seedlings and graze them (Smit *et al.*, 2006). The grazing/browsing pressure on palatable seedlings may be reduced to some extent if they are protected by bordering unpalatable plants (Smit *et al.*, 2006; Van Uytvanck *et al.,* 2008). Rotational grazing can also improve seedling/ sapling growth and help in regeneration (Van Uytvanck and Verheyen, 2014). This can be overcome to some extent by identifying and encouraging the regeneration of multiple-use tree species and restricting their cutting for a few years so that the tees get mature. Another approach can be to complement local demand by plantation commercial or multiple-use plants separately; this may reduce the pressure on regenerating natural forest.

The forest regeneration mechanism operates through ground vegetation (Nilsson *et al.*, 1998). Recent research indicates that large-scale forest recovery projects should combine passive reforestation (Chazdon, 2014), tree planting (Brancalion and Holl, 2020), and applied nucleation (Holl *et al.*, 2020). Applied nucleation is a restoration mechanism where a patch of planted woody vegetation enhances the deposition of seeds and later establishment of other individuals and species (Benayas *et al.,* 2008). This approach aims to overcome limitations by mimicking the natural regeneration process.

Ecological theory about plant-plant interactions has the potential to have significant consequences for low-cost restoration (Löf, 2017). The most common method of managing vegetation during regeneration and restoration is through negative interactions, which lessen competition from unwanted plants.

Fertilization and irrigation regimes are important aspects to encourage the establishment and growth of seedlings. Recent studies indicated that Nitrogen and Carbohydrates as stored reserves are important to resist environmental stresses and seedling growth on the planting site (Villar-Salvador *et al.,* 2015; Uscola *et al.,* 2015). Field fertilization, soil amendments, and tree shelters (Rose *et al.,* 2016; Löf, 2017; Oliet *et al.,* 2019) will promote regeneration and restoration success.

Environmental conditions determining tree recruitment as well as the biological processes that amplify plant fertilization and recruitment dynamics, such as seed dispersal or effective pollination should be considered while planning restoration through natural regeneration (Farwig and Berens, 2012; Potts *et al.,* 2016).

Even when regeneration is assisted, the cost of restoration is substantially lower than those with large-scale tree-planting approaches (Brancalion *et al.*, 2016; Chazdon and Uriate, 2016). Though natural regeneration of trees may provide a cost-effective way to restore degraded tropical dry forests, the site-specific factors predominantly affecting natural regeneration success need to be understood.

A wide range of activities, from passive restoration techniques that employ economically viable interventions to promote autonomous tree regeneration, are included in strategies to achieve healthy, diversified, and multifunctional second-growth forests (Benayas *et al.,* 2008).

CONCLUSION

Many causes are identified that play crucial roles in the regeneration of natural forests. These causes may be site-specific. Thus, identifying such causes may help to prepare a suitable plan that assists and encourages the natural regeneration of forests. Based on the present status of forests and their regeneration status, it is suggested that assisted regeneration and implementation of restoration techniques in later stages are necessary to restore forests to their natural pre-disturbance status.

Conflict of Interest - None

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