Journal of Medicinal Plants Studies
www.PlantsJournal.com

ISSN (E): 2320-3862
ISSN (P): 2394-0530
https://www.plantsjournal.com
JMPS 2023; 11(5): 129-136

Received: 09-08-2023
Accepted: 11-09-2023

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Impact of climate change on natural regeneration status of forest landscape in Damoh region of Madhya Pradesh

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DOI: https://doi.org/10.22271/plants.2023.v11.i5b.1597

Abstract
Climate change is a reality which is also caused by human activities that alters the composition of the global atmosphere and which is in addition to natural climate variability. To quantify the changes in natural regeneration due to natural climate variability, a study was conducted in Damoh Forest Region covering over five decades. Out of 686 forest compartments in Damoh Forest Division, 42 forest compartments were studied covering 6.12% of the area. Changes in natural regeneration status were determined into three classes i.e. 'improvement', 'deterioration' and 'unchanged'. Different categories of natural regeneration were termed as profuse, adequate, inadequate and poor. 'Adequate' regeneration has been recorded in the latest compartment history for only one compartment (compartment no. PF 236) of Damoh Forest Range. In the latest compartment histories of all the remaining 41 studied compartments, the regeneration status has been recorded as 'inadequate'. There is no compartment having 'profuse' or 'Poor' category of regeneration status. Thus, natural regeneration in the study area is generally 'Inadequate'. Out of 42 forest compartments, improvements in natural regeneration was found only in 06 compartments (14.28%), deterioration was observed in as many as 27 compartments (64.28%) and unchanged status of natural regeneration was found in 09 compartments (21.42%). Thus, there has been deterioration in the regeneration status in majority of the studied compartments. Both, climate and non-climatic factors might have been responsible for this deterioration. Restocking of forest is needed by seed sowing or planting of seedlings after timber harvest among climatic factors erratic and deficient rainfall could be the main factor.

Keywords: Damoh, natural regeneration status, forest manager, climate change, forest compartments

Introduction

Climate change is one of the most serious challenges facing the world today, which is expected to have long term impacts on sustainable living. It is considered to affect the environment, vegetation, agriculture, health, power, transportation and other allied sectors that are vital for the existence of mankind. Human activities have already caused an average 0.87 °C of warming over preindustrial levels, with warming likely to reach 1.5-2 °C between 2030 and 2052 (IPCC, 2018) [15]. Global warming affects physical and biological systems in many ways that affect ecosystem services and human well-being. This includes changes to extreme weather conditions such as heat waves, drought and precipitation that can profoundly affect regeneration and ecological systems, and directly impact people by endangering life or property. In India, climate change is a particularly serious challenge that will significantly impact the Indian economy and the livelihoods dependent on it due to a high reliance on climate-sensitive sectors, such as agriculture and forestry (Sharma and Chouhan, 2011) [21].

Adverse impacts of climate change have already been observed on natural resources; the environment and forest ecosystems; agriculture and food security; human health and settlements; economic activity and physical infrastructure (IISD, 2007) [14].

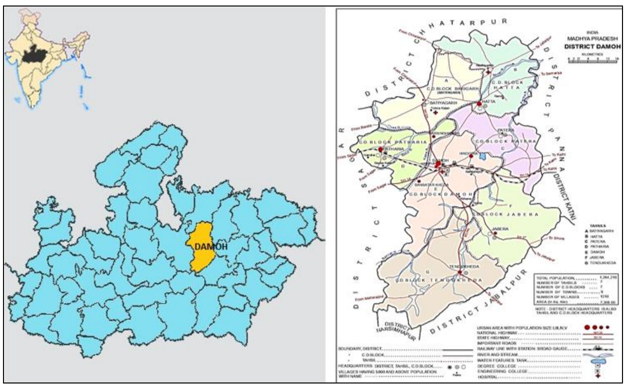
Natural regeneration is the process by which woodlands are restocked by trees that develop from seeds that fall and germinate in situ. Seedling establishment of some species has been observed by following the growth and survival of tree species growing after silvicultural operations to promote natural regeneration. Forests are critical, in terms of day-to-day livelihoods for millions of poor people, particularly in the developing world (FAO, 2013) [10]. Naturally or "passively" restored forests certainly do a better job at bringing back biodiversity than monoculture plantations. But it's slow.

It can take centuries of regeneration before the original assemblage of species return in numbers. The spontaneous (meaning unassisted) recovery of forest cover from seeds or rootstocks already present in the soil or newly dispersing from neighboring forests. This type of restoration happens regardless of any kind of human intervention, including site protection, and is often a by-product of unplanned land abandonment triggered by larger socio economic forces. In this case, natural succession happens uninhibited and requires no support (Shono *et al.*, 2007; Crouzeilles *et al.*, 2017) [23, 8].
Although the natural forest regeneration success depends on events occurring during the whole tree lifespan, some stages such as seedling establishment, survival and early growth are critical (Borja, 2014; Kozlowski, 2002) [5, 17]. Climate change, habitat fragmentation, loss of animal seed dispersers and fires can act together to slow biodiversity recovery. Still, this shouldn't discourage us from naturally restoring forests to protect biodiversity (Guariguata, 2020) [13].
Growth in regeneration from vegetative parts in much faster than that in seedling regeneration. Success percent in establishment of regeneration is also better as these are hardier as compared to seedling regeneration. However, their life is much shorter as compared to seedling regeneration. Moreover, all species do not have coppicing power. Coniferous species normally do not possess coppicing ability. Even many broad-leared species too are not good coppicers. So, for long term sustainability and to get large-sized timber of good quality, it is advisable to go for seedling regeneration only. The forest developed from seedling regeneration is called 'high forest'.
In many forests, natural tree regeneration is a key process in ensuring forest sustainability and a relatively slow process, with the initial stages of the plant life cycle being critical for natural regeneration dynamics. Natural regeneration takes place in a very complex scenario but seedlings are particularly suitable for exploring species responses to changing resource levels. The natural regeneration in a multidimensional space where many abiotic and biotic factors act simultaneously and interactively, and these interactions could be sometimes even more important that the main effects. Thereby, regeneration, growth and mortality are the main processes driving plant community dynamics.
Madhya Pradesh is a forest rich state and is ranked first among the states in terms of the Reserved Forest Areas (RFA). The State has recorded forest area (RFA) of 94,689 sq km which is 30.72% of its geographical area. The reserved, protected and unclassed forests are 65.36%, 32.84% and 1.80% of the recorded forest area in the State respectively. The State has a sizeable tribal and rural population which is dependent on the forests for their livelihood and basic needs. (FSI, 2019) [12].
The study area Damoh has total geographical area of 7,306 sq. km. Out of which, forest area is 2,587.18 sq. mt. mostly dominated by open forest 1,739.39 sq. km, followed by moderate dense forest 845.79 sq. km and very less distribution of very dense forest i.e. 2 sq. km. This forest area constitutes 3.41% of its total geographical area (FSI, 2019) [12]. Scrub area is also distributed up to 127.61 sq.km. As per the assessment of Forest Survey of India (FSI, 2017) [11] the change WRT of Damoh has decreased by -6.82 sq. km in the year 2019.
Apart from various negative impacts of increased CO_2 concentration, some positive impacts have also been reported. Increase in atmospheric CO_2 results in enhanced photosynthetic capacity, increased growth and increased production of secondary metabolites (Steffen *et al.*, 2005) [28].
Changes in post-fire regeneration have been observed in recent decades in many parts of the world and have been attributed mainly to ongoing climate change (Donato *et al.*, 2016; Rother and Veblen, 2016; Stevens *et al.*, 2017) [9, 19, 27].
Forests can play an important role in mitigation and adaptation to climate change and it can be a part of solution. It helps stabilize the climate as they regulate ecosystems; protect biodiversity; play an integral part in the carbon cycle; support livelihoods and can help drive sustainable growth. Forests and climate are closely interrelated and impact each other. Whenever a significant change in climate takes place, it may affect the forest, particularly regeneration, phenological pattern and functioning of forest ecosystem in natural ways (Bennett, 2017) [4].
To maximize the climate benefits of forests, forest landscapes should be kept intact or managed more sustainably. Restoration of more of those landscapes which have been lost, halting the loss and degradation of natural systems and promoting their restoration have the potential to contribute over one-third of the total climate change mitigation which climate scientists say, is required by 2030. Restoring 350 million hectares of degraded land in line with the Bonn Challenge could sequester up to 1.7 Giga tonnes of carbon dioxide equivalent annually (IUCN, 2017) [16].

Materials and Methods

Study area

Damoh Forest Division is geographically located between 23°09' N to 24°26' N latitude and 79°3' E to 79°57' E longitude. It comes under the Vindhyan plateau agro-climatic zone of Madhya Pradesh. The total geographical area of Damoh Forest Division is 7306 sq km out of which forest area is 3093.95 sq km which is 42.34% of the total geographical area (Baghel, 2018) [3]. The forest is southern tropical dry-deciduous mixed forest (5A/C3) as per Champion & Seth's classification of forests types. Almost the entire area is undulating and hilly. The plain area lies between 460 m to 515 m above MSL. Climate is hot and dry. The range of variation of maximum temperature during summers is 40 ºC - 47.5 ºC, usually in June and that for minimum temperature in winter is 0 ºC-11 ºC, usually in January. Because of the horizontally bedded impervious sandstones, availability of water becomes acutely deficient, especially during summer season (Shrivastava, 2005) [22]. Map-1 shows the location of Damoh district in the map of Madhya Pradesh state.



Map 1: Location of Damoh district in Madhya Pradesh

As per the recent working plan of Damoh Forest Division by R.P.S. Baghel (2018) [3], forests occupy 42.34% of total geographical area of Damoh district and the total forest area in the district is 3093.95 sq km. Out of this, some forest area has been transferred to Panna Tiger Reserve. Total number of trees are 3, 32, and 43,708 in the working plan area and their volume is 1584535.90 cmt Average number of trees per hectare is 137 and average volume per hectare is 6.53 cmt in the Working Plan area. Forest regeneration is 298 per ha. The Biodiversity Index value as per Forest resource survey done in 591 grids by Shannon Wiener formula (3.5 to 1.5) is 1.74, whereas it is 0.88 as per Simpson's formula (1 to 0) (Baghel, 2018) [3].

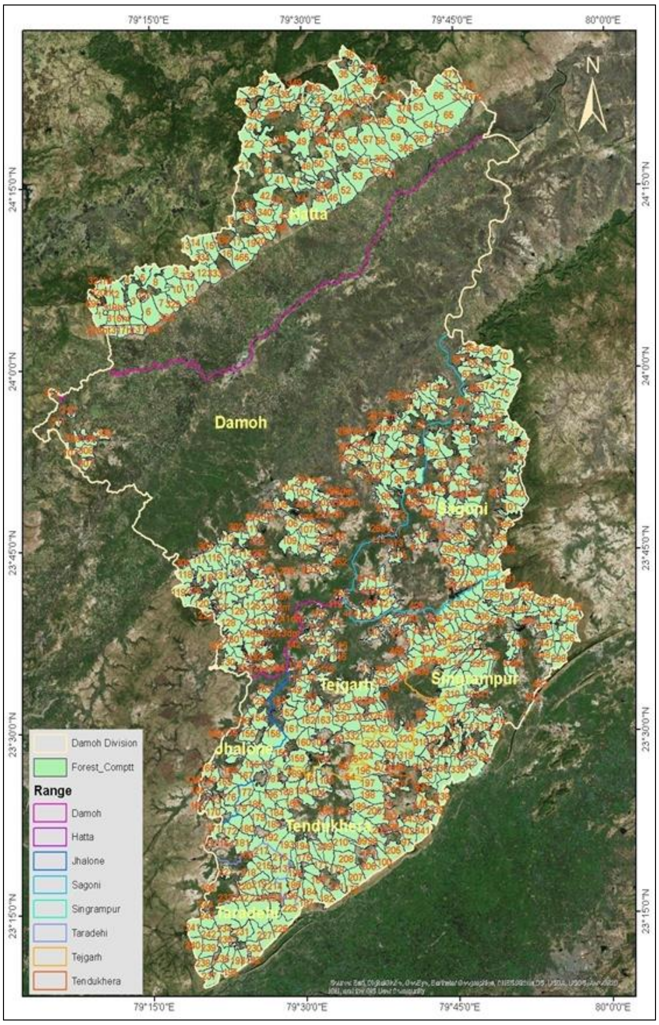
Methodology

To assess the impact of climate change on natural regeneration secondary data was obtained from compartment histories of Damoh Forestry Working Plan as it was the only available and authentic sources of secondary data. These working plans are prepared after conducting detailed field survey in each compartment. The plans are normally revised at an interval of 10 years and therefore, periodic information is available for the study of temporal changes on various aspects. We have liberally used the qualitative and quantitative data available in working plans of Damoh Forest Division. List of working plans made available and consulted for our study is given in Table-1.

Table 1: List of Forest Working Plans of Damoh Forest Division used as secondary data sources during the study

S. N.	Working Plan Period	Name of the Working Plan Officer who prepared / revised the plan
1.	1951-52 to 1965-66	S.H. Mahalaha
2.	1970 to 1986	A. M. Sagri
3.	1993-94 to 2003-04	L. R. Burdak
4.	2005-06 to 2015-16	Rajesh Shrivastava
5.	2016-17 to 2026-27	R.P.S. Baghel

There are total 686 forest compartments and eight forest ranges in Damoh (Map-2) out of which, 42 sample compartment histories (covering 6.12%) were selected for the study. In order to study the changes in the status of natural regeneration during past six decades, past compartment histories of the same 42 compartments updated during the previous revisions of the working plan of Damoh Forest Division were consulted and the available data were analyzed. The selective sampling was done after consulting the forest officers of the area. First, those compartments (from all eight ranges) were selected in which information was available for at least six decades. Then out of those short listed compartments, more compartments were selected from those forest ranges where biotic pressure and grazing was believed to be comparatively less. The forest ranges in which comparatively less biotic pressure was found are- Singrampur, Jhalon and Sagoni. From each of these forest ranges, at least 06 to 08 compartments were selected.



Map 2: Map of all forest range and compartments in study area

List of selected compartments from various forest ranges, for detailed study of impact of climate change on natural regeneration is given in Table-2.

Table 2: List of selected compartments for the detailed study on natural regeneration

S. No.	Forest range	Selected Compartments	Total
1.	Damoh	PF-127, PF-235, PF-236, RF-98	04
2.	Hata	PF-339,PF-342, PF-343, RF-01	04
3.	Jhalon	PF-129, PF-140, PF-145, RF-157, RF-165, RF-167, RF-170	07
4.	Sagoni	RF-68, RF-383, RF-384, RF-399, RF-400, RF-401	06
5.	Singrampur	PF-71, PF-77, RF-311, RF-338, RF-430, RF-447, RF-448, RF-449	08
6.	Taradehi	PF-191, PF-192, PF-193, PF-194, PF-195	05
7.	Tendukheda	PF-163, RF-175, RF-200, RF-340, RF-342	05
8.	Tejgarh	PF-106,RF-163, RF-333	03
Total			42

Results Discussion

The classical method of categorization of regeneration is quite cumbersome and difficult to follow by front line staff of forest department. Hence, a simpler categorization is now in used. According to the new classification, the regeneration status can be categorized as profuse', 'adequate', 'inadequate' and 'poor' depending on the number of established seedlings (or equivalent number of woody shoots and/or whippy seedlings). Table-3 gives the description of these new categories of which the regeneration change matrix can be understood. Geographical locations of 42 compartment histories are shown in Map-3.

Table 3: Number of established seedlings of regeneration for different categories

S. No.	Category of regeneration status	Minimum number of established seedlings per hectare
1.	Profuse	72,500
2.	Adequate	1500-2500
3.	Inadequate	500-1500
4.	Poor	<500

Source: Working Plan Code of M.P Forest Department

Improvement in the regeneration status

In the span of more than six decades, some positive changes in regeneration were observed therefore, in Table-4, list of 06 compartments belonging to 04 different ranges, are shown. In these compartments the regeneration status has improved from 'poor' to 'inadequate' category (Table- 4).

Table 4: Compartments where regeneration status has improved from 'poor' to 'inadequate' category

S. No.	Range	Compartment number	No. of compartments
1.	Damoh	PF 127, RF 98	02
2.	Jhalon	RF 170	01
3.	Tejgarh	RF 333	01
4.	Tendukheda	RF 200, 340	02
Total			06

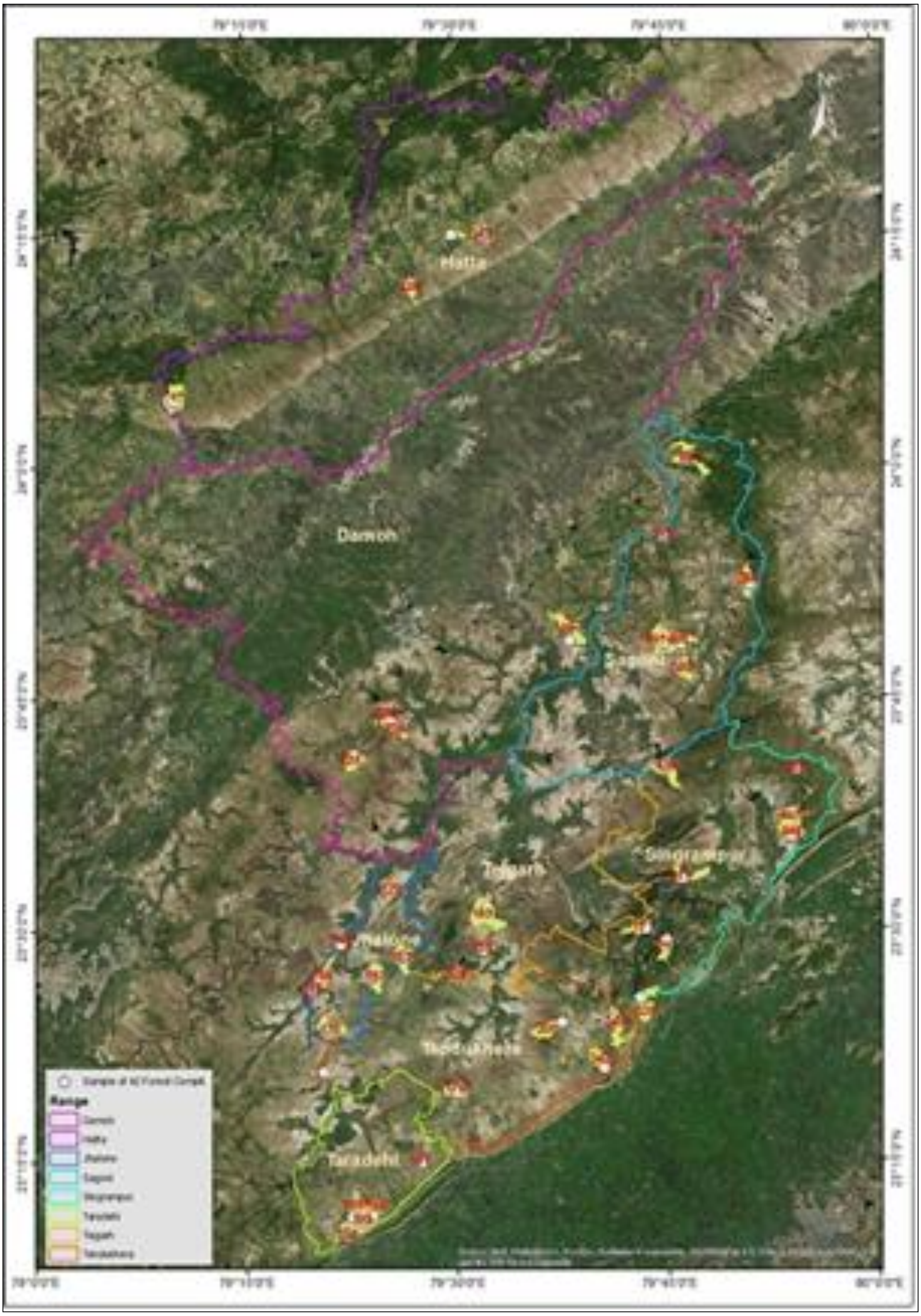
It might have happened as a result of better silvicultural working and protection from grazing and forest fires.

Deterioration in the regeneration status

A total of 27 out of the 42 studied compartments, the natural regeneration status has deteriorated from 'adequate' to 'inadequate' category (Table-5).

Table 5: Compartment where regeneration status has deteriorated from 'adequate' to 'inadequate' category

S. No.	Range	Compartment numbers	No. of compartment
1.	Damoh	PF 235	01
2.	Hata	RF 01, PF 339, 343	03
3.	Jhalon	PF 140, RF 157, 165, 167	04
4.	Sagoni	RF 384, 399, 400, 401	04
5.	Singrampur	PF 71, RF 311,430,447,448, 449	06
6.	Taradehi	PF 191, 192, 193, 194, 195	05
7.	Tejgarh	PF 106	01
8.	Tendukheda	PF 163, RF 175 and 342	03
Total			27



Map 3: Geographical locations of 42 compartment histories in Damoh

Thus, there has been deterioration in the regeneration status in majority of the studied compartments. Both, climate and non-climatic, factors might have been responsible for this deterioration. Among climatic factors, erratic and deficient rainfall could be the main factor. However, the main culprits are definitely biotic factors, especially unregulated cattle grazing and deliberate forest fires by gatherers of NTFPs, especially tendu leaves and mahua flowers.

Status quo in the regeneration status

Regeneration status in 09 out of the 42 studied compartments has all along remained unchanged (Table-6).

Table 6: Compartments where regeneration status has remained 'unchanged'

S. No.	Range	Regeneration status	Compartment numbers	No. of compartments
1.	Damoh	Adequate	PF 236	01
2.	Hata	Inadequate	PF 342	01
3.	Jhalon	Inadequate	PF 129, 145	02
4.	Sagoni	Inadequate	RF 68, 383	02
5.	Singrampur	Inadequate	PF 77, RF 338	02
6.	Tejgarh	Inadequate	RF 163	01
Total				09

Thus, in one compartment (PF 236) of Damoh Forest Range, the regeneration status has all along remained 'adequate' whereas in eight (08) compartments of five (05) ranges, the regeneration status has all along remained 'inadequate'.

Overall changes in the regeneration status

Overall changes in the regeneration status in different 42 studied compartments is shown in the following change matrix (Table- 7).

Table 7: Regeneration status change matrix

S. No.	Direction of change	Regeneration status categories		No. of Compartments
		From	To	
1.	Status quo (No change)	Adequate	Adequate	01
		Inadequate	Inadequate	08
	Sub-total			09
2.	Improvement	Poor	Inadequate	06
3.	Deterioration	Adequate	Inadequate	27
Total				42

From the above table, it can be seen that earlier, regeneration was 'adequate' in 28 compartments and in 27 of these 28 compartments, the regeneration status has come down to 'inadequate' level. As already discussed, causes for this deterioration could be both climatic and biotic. Amidst this gloomy scenario, there is a silver lining of hope also. In 06 out of 42 studied compartments, the regeneration status has improved from 'poor' to 'inadequate' category. It shows that adverse impacts of climatic change and increased biotic pressure can be successfully countered by proper management of forests.

Conclusions

Impact of climate change on natural regeneration

For good germination, there should be fine synchronization between seed fall and onset of monsoons. If onset of monsoon is delayed, the seeds fallen on the forest floor will not germinate.

There are two stages of natural seedling regeneration. First stage is of seed germination and the second is of establishment of the germinated seedling. Change in climate can affect the natural regeneration in both of these stages. For successful germination, there should be optimum climatic conditions at the time of seed fall or during the period of seed viability. Seeds of some species, e.g. Sal (*Shorea robusta*), remain viable for only very short period. Hence, if the seed bed is not ready at the time of seed fall or within the short viability period, the seed will fail to germinate. In the context of global change, changes in temperature, rainfall patterns, biogeochemical cycles and land use have already been recorded worldwide and are predicted to intensify in the future (Canadell *et al.*, 2007) [7].

The challenge is to identify strategies that reduce the uncertainties associated with where assisted natural regeneration of forests can occur and persist, while maximizing the multiple benefits arising from forest restoration" (Crouzeilles *et al.*, 2017) [8]. We conclude that we don't have conclusive evidence to deterioration of natural regeneration is a result of climate change only. According to FSI, 2019 [12], however, with increasing population, developmental activities and practices like jhuming, the pressure on forest resources is consistently increasing, leading to their degradation and affecting regeneration and productivity. (FSI, 2019) [12]. The improvement of the quality of forests is high in the priority and regeneration activities are carried out regularly.

Although our review reveals that information is lacking for some regeneration stages, it highlights the response variability to climate conditions between species. The recruitment process of black spruce is likely to be the most affected by rising temperatures and water deficits, but more tolerant species are also at risk of being impacted by projected climate conditions (Boucher *et al.*, 2019) [6].

Study conclusion

There was no primary data regarding natural regeneration in forests of the study area during the present investigation. However, secondary data recorded in compartment histories of 42 forest compartments made available by forest department, was used in the present analysis. As per the regeneration status recorded in these 42 studied compartments, 'adequate' regeneration has been recorded in the latest compartment history of only one compartment i.e. PF 236 of Damoh Forest Range. In the latest compartment histories of all the remaining studied compartments, the regeneration status has been recorded as 'indequate'. There is no compartment having 'profuse' or 'poor' category of regeneration status. Thus, natural regeneration in the study area is generally 'inadequate'.

Climate change may also affect the timings of the onset and retreat of monsoon, number of rainy days and the amount of rainfall. Thus, it has the potential to disturb the delicate synchronization between phenology and rainfall. Earlier study by Shukla *et al.*, 2020 [24] suggested that, in Damoh there are signs that, in coming years, rainfall will be more unpredictable in terms of both magnitude and distribution.

Rise in temperature accompanied with hot winds increases the rate of desiccation of surface soil on the forest floor. In the absence of soil moisture, the seed will fail to germinate. Seeds of some species, such as teak (*Tectona grandis*) have very hard seed coat. The seed will germinate only after the seed coat is broken in the natural process of weathering and for which optimum temperature and soil moisture are required. Similarly, certain seeds have dormancy period. These seeds can germinate only after their dormancy is broken till then, the seeds lying on the forest floor are vulnerable to attacks from insect pests and diseases. Climate change further increases this vulnerability.

Needs of adaptation to enhance natural regeneration

A host of approaches and tools may be used to adapt to changing conditions such as climate change (Sohngen, 2007; Seppala *et al.*, 2009) [25, 26], with a major set of adaptations associated with the planted forest. A decision to plant also involves considerations with respect to location, choice of species, and quality of the stock to be planted. The planting approach allows regeneration to be for the species of choice, which is often a rapidly growing species appropriate for intensively managed industrial forests. This choice can be desirable for timber production and/or for other forest values. Forest managers may have to make adaptations during climate warming including changing of rotation periods. A replanting species is regeneration is inadequate, where damage is incurred, replanting of new species if conditions require working plans may need to adjust as per scenarios.

In a rapper on forest adaptation to climate change, Roberts (2009) [18] points out those policies that serve multiple purposes can be useful in adapting to climate change. He notes that some forest managers are already beginning to anticipate climate change in their management decisions. He also points out that existing policies tend to be reactive rather then proactive. Given the uncertainties of how climate is likely to affect any specific forest, however, one might maintain that a reactive policy with a high degree of flexibility is highly appropriate. Climate changes may reduce the success of natural regeneration and hence require adjustments to silvicultural practices. Seed germination and emergence represent important phenological events that influence the success of the initial seedling recruitment (Borja, 2014) [5].

Recommendations

Extreme temperature conditions also inhibit germination (Ryan, 2010) [20]. Moderate temperature and adequate soil moisture are necessary conditions. Porosity and soil aeration are other requirements for roots of the new seedlings to be able to penetrate. For the establishment of a new born seedling, adequate sunlight and soil moisture and protection from grazing and fire are prerequisites. Quite often, a large number of seeds do germinate but most of the germinats subsequently die and very few seedlings are able to get established. An established regeneration is the stage when young regeneration is considered safe from normal adverse influences, such as frost, drought and weeds. Main objective of the scientific forest management is to create or maintain favorable conditions for germination to come up and get itself established in adequate numbers.

Besides the aforementioned seedling regeneration from seeds, regeneration can be obtained from vegetative parts also, such as from stump sprouts, pollard cutting and root suckers. When a tree is cut at the ground level, the sprouts come up from the stump. These coppice shoots derive food material from the root stock of the felled tree. For proper growth, only one or two healthy coppice shoots are retained and the other coppice shoots are removed. This process is called ‘singling’. When instead of cutting at ground level, the tree is cut at a height at the end of the straight portion of the stem, it is called pollarding and the shoots later sprouting from the cut surface are called pollard shoots. When root of a tree is damaged and shoots come up from the damaged root portion, these are called root suckers. These root suckers may, later on, develop their own independent root system and become separate plants, independent of the mother tree. All these methods of regeneration from vegetative parts have some ‘plus’ and ‘minus’ points as compared to seedling regeneration.

As against natural regeneration, artificial regeneration is the process of restocking of forest by seed sowing or planting of seedlings after timber harvest rather than relying on seeds naturally fallen from standing trees or stump sprouts or other forms of natural regeneration. Artificial regeneration can be restored to in following cases: (1) When natural regeneration of desired species is difficult to come up or to get established; or (2) When the objective is to convert the uneven aged crop to even aged crop under ‘conversion to uniform’ silvicultural system: (3) or when it is intended to change the crop composition.

Acknowledgement

We place on record our sincere gratitude to the Chief Conservator of Forests (CCF), Working Plan, Sagar, for providing the record on compartment histories of Damoh Forest Division. We also express our deep sense of gratitude to APCCF, Research, Extension and Lok Vaniki, Madhya Pradesh Forest Department for providing financial assistance to accomplish this study.

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