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Putting ducks in a row: Village resettlement prioritization from inside tiger reserves and its implication in achieving global conservation goals for India

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Abstract

Following the local extermination of tigers from India's two premier reserves, village relocation as a policy to create more inviolate space for tiger breeding was conceived by the Indian Government a decade ago. However, given the significant number of human settlements inside tiger reserves, it is neither feasible nor realistic to consider all villages for relocation. There is an urgent need to prioritise villages for relocation to maximise conservation benefits. Here, we developed a framework for prioritizing village relocation by setting national, landscape and site-specific goals. We have identified ten source sites in Central India and Western Ghats tiger landscapes for immediate attention for conservation-related resettlements. Our study shows that village resettlement prioritization provides an optimum level of conservation success at a much-reduced budget. The scenario will help increase tiger numbers and reduce conflict by increasing inviolate space at site, landscape, and national levels. This approach will help India achieve global conservation targets for tigers with minimum conflict.

Keywords: village relocation prioritization, Aichi targets, tiger conservation, protected area network

Introduction

Habitat loss imperils species both locally and globally. The inception of protected area networks served as a tool to stall habitat loss, deter species extinction, and ensure the safeguarding of ecosystem services that these areas provide (IUCN & UNEP 2009). Globally, more than 1,50,000 protected areas cover 12% of the global land surface (Bertzky *et al.*, 2012; Joppa & Pfaff 2010; Laurence *et al.*, 2012). However, in densely populated South Asia, habitat loss inside and outside protected areas are similar (Clark *et al.*, 2013; Heino *et al.*, 2015; Leberger *et al.*, 2020; Wolf *et al.*, 2021; Yang *et al.*, 2021). A quarter of the land inside South Asia's protected areas is human-modified, requiring intensive management (Kamath *et al.*, 2024). Conservation-related resettlements of villages in these protected areas have been central to conserving the remaining pristine habitats during the last century (Carruthers 1995; Neumann 1998; Fenari 2019).

India, one of the world's 17 mega-biodiversity countries that sustain 18% of the world's growing human population, epitomizes the complex conservation scenario of conserving habitat from growing human pressure (Mettermeier *et al.*, 2005; Mathur *et al.*, 2014). While 1014 protected areas cover approximately 5% of India's geographical area (wii.gov.in/nwdc), over 65% are characterized by human settlement (Kothari *et al.*, 1989). In India, approximately five million people live inside these protected areas, and another 147 million depend on the resources these areas provide. Given the 18% increase in the human population since 1990 in India, the dependence on the resources of protected areas is likely only to increase.

Indian tiger population epitomizes the complex conservation scenario of conserving the species in fragmented habitats surrounded by human habitations. While considered significant for protecting tigers, these protected areas were additionally designated as a Tiger Reserve consisting of a core/critical tiger habitat and buffer zone. Core/Critical Tiger Habitats are managed as an inviolate area. Covering only 2% of India's landmass, these tiger reserves are, on average, 1431.55 sq. km. in size with an average core of 791.15 sq. km. and an average buffer of 640.41

sq. km. surrounded by human settlements (Nautiyal *et al.*, 2023, NTCA 2024). However, these tiger reserve's core is also not devoid of human habitation and out of the designated 55 tiger reserves, only 23 have core areas of more than 800 sq. km., a minimum requirement for sustaining tiger population over time. There are roughly 1500 villages with 65,000 families living inside the core and buffer areas of tiger reserves in India (Ministry of Environment & Forests 2005), indicating tremendous pressure on the last refuge of tigers. Indian human population is growing at a projected growth rate of 1.1% (MOSPI, 2021), which increases the likelihood of conflict and consequently reduces support for conservation.

To conserve genetically and demographically viable populations of tigers, conservation biologists advocate for a landscape approach and the protection of core breeding populations (Dinnerstein *et al.*, 2006; Walston *et al.*, 2010). They argued that long-term survival of medium-sized tiger populations (24 breeding females in a population of 100 tigers) can be achieved with efforts to increase population size by enhancing habitat quality and availability concurrently with securing habitat connectivity (Kenney *et al.*, 2014). While large inviolate stretches of forests of approximately 800 -1000 sq. km. are required to sustain a population of 100 tigers, these landscapes are becoming increasingly rare. Following the tiger population extermination between 2004-2005 in Sariska Tiger Reserve, Tiger Task Force Report called for priority to be given to resettlement from the core areas of the Tiger Reserves for the long-term survival of the species (Ministry of Environment & Forests 2005) and suggested scientific assessment for the basis of village relocation. However, national-level scientific planning for village resettlement needs to be included. If India has to achieve global conservation targets for tigers, India needs to manage its protected areas substantially. Given the number of human settlements inside tiger reserves, relocating all the villages is neither feasible nor realistic. There needs to be a better way of prioritizing conservation efforts. A practical roadmap is crucial in achieving these global goals. In the present study, we call for landscape-level prioritization and, consequently, site-level prioritization for village relocation to achieve optimum conservation success. While restoring connectivity between tiger populations is crucial, securing source sites is essential to maintaining meta-population dynamics.

Methods

National Level Prioritization

The voluntary resettlement of villages from the notified core/critical tiger habitat is done under the centrally sponsored scheme of Project Tiger as per provisions contained in the Wildlife (Protection) Act, 1972, as amended in 2006, read with the Scheduled Tribes and Other Forest Dwellers (Recognition of Forest Rights) Act, 2006 on mutually agreed terms and conditions. Currently, NTCA has two packages for the families agreed for voluntary relocation, *i.e.*, cash (17,840 USD/Family) or land package. A family includes an adult (over 18 years) and on the imperative of his marital status, an unmarried daughter or sister over 18 years old, a minor orphan, a widow, or a divorcee depending upon their marital status, a physically and mentally challenged person (1 USD = 84 INR). India has five tiger conservation landscape complexes (Figure 1; Jhala *et al.*, 2015; NTCA 2020). To prioritize landscapes at the national level for tiger conservation, we evaluated tiger population estimates, the number of villages, and the landscape complex's potential for sustaining tiger populations over the long term. Our primary goal was to accommodate more tigers concurrent with the global conservation goal for tigers and to minimize human-animal conflict at the national level. We used management effectiveness evaluation of 51 tiger reserves (Yadav *et al.*, 2023) for detailed information on villages. We have estimated the cost to the Indian Government to relocate all the villages from inside tiger reserves landscape-wise. Tiger population estimates of the landscape complex were from Qureshi *et al.*, 2023.

Landscape Level Prioritization

To prioritize tiger reserves at the landscape level for village relocation, we considered tiger density, prey density, core area, and the number of villages within critical tiger habitats collated from published reports. This prioritization focused on maximizing tiger populations at connected source sites to enhance gene flow and maintain meta-population dynamics. From this process, we selected one tiger reserve from the top priority list as a case study for site-level village resettlement planning. Tiger and prey density estimates were sourced from Qureshi *et al.* (2023), while data on core area and village numbers within CTH were taken from Yadav *et al.* (2023).

Site Level Prioritization

Our site-level prioritization aimed to increase inviolate areas for tiger breeding at the reserve level and minimize human-tiger conflict effectively. We considered Sariska Tiger Reserve among the priority list for site-level analysis as a case study. Sariska Tiger Reserve sustains a well-monitored reintroduced tiger population (Sankar *et al.*, 2010 & 2013). Even though Sariska's tiger reintroduction was a success, the fast population recovery was missing, as seen in Panna's reintroduced population (Bhattacharjee *et al.*, 2015). An earlier study found that tigers of Sariska, especially females, are stressed due to human disturbance affecting their breeding (Bhattacharjee *et al.*, 2015). Studies also have linked anthropogenic disturbance with stress and reduced reproductive success in wildlife. Studies suggested that habitat complexity and quality are key factors that influence how animals perceive and adapt to these disturbances, ultimately leading to chronic stress and lower reproductive outcomes (Malviya *et al.*, 2018).

However, after relocating 565 families, tigers started breeding, giving us the perfect opportunity to study the underlying factors. Sariska is now an isolated reserve with a sharp boundary with human habitation. There are 29 villages inside Sariska. People inhabiting these villages are traditionally pastoralists, primarily from the Gujjar community. Srivastava *et al.* (2013) reported extensive pressure on habitat due to the presence of these villages. Resource extraction and extensive livestock grazing create competition for wild ungulates, leading to weed proliferation and habitat degradation.

Radiotelemetry (n = 4), direct sighting, camera trapping, and pugmark tracking were used to monitor individual tigers during the study period (2013 – 16). Seven annual home range polygons of seven adult females were considered to study the factors governing tigers' breeding and spatial dynamics. The polygons were further classified as breeding/ non-breeding. The home range polygon was classified as 'breeding' if the female was accompanied by cub(s). The photo capture rate of humans and livestock, distance to village, road and waterholes, prey availability and ruggedness were used as variables to understand the influence of different variables on the breeding of tigers using multiple linear regression. Multiple linear regression was used to predict suitable breeding areas using ArcGIS for tiger breeding in Sariska. We used Jenks (1967) natural breaks to categorize suitable breeding areas (*i.e.*, High, medium and low) to prioritize villages for relocation at the site level.

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Results

National level Prioritization

The total number of villages was 666 inside India's critical tiger habitat or core area of the tiger reserves. 489 villages have 58,831 families. Additionally, 177 villages need more information on number of families. In total, 1049.54 million USD is required to relocate the reported families. In total, 1365.31 million USD is needed to relocate all the villages from inside tiger reserves (assumed 100 families/ village with no information on families). Amongst the five tiger conservation landscape complexes, the central Indian tiger landscape (n=348) has the most number of villages inside the core areas of the tiger reserve, followed by the western ghat tiger landscape (n=181) (Figure 1), which are to be prioritized at the national level.

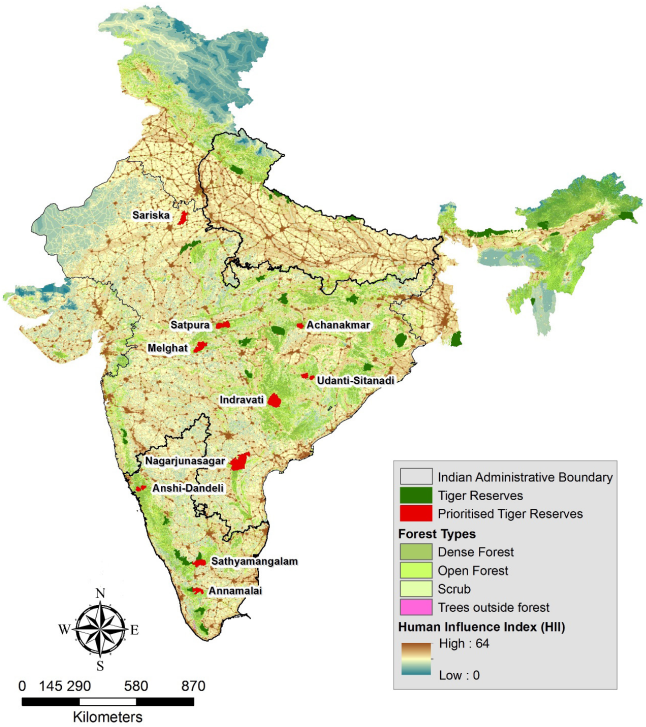

Figure 1: 10 tiger reserves identified for village relocation prioritization (Human Influence Index was taken from Sanderson *et al.* 2006)

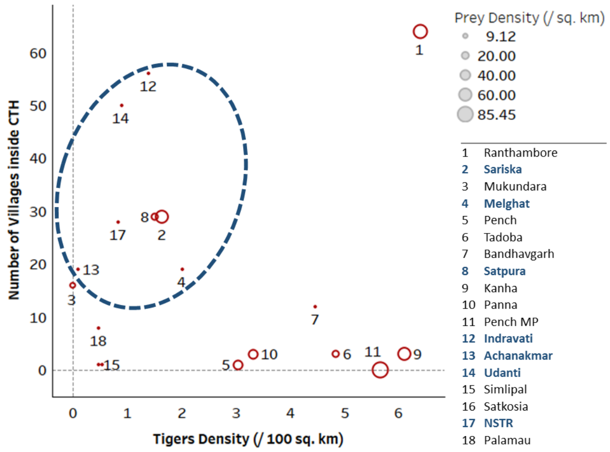

Figure 2: Prioritized tiger reserves for village relocation in Central Indian Tiger Landscape (Circle size denotes prey availability)

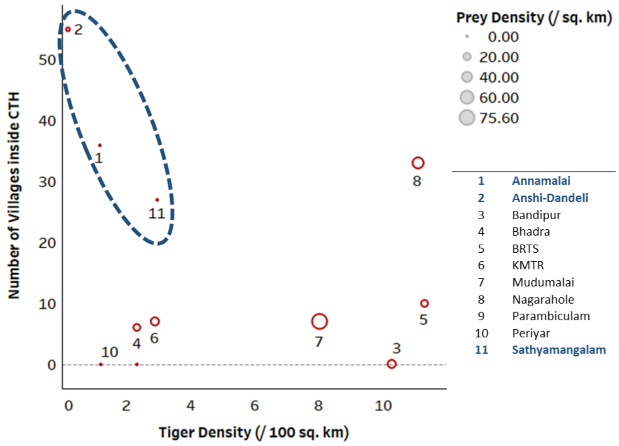

Figure 3: Prioritized tiger reserves for village relocation in Western Ghats Tiger Landscape (Circle size denotes prey availability)

Landscape Level Prioritization

At the landscape level, we recommend prioritizing conservation efforts for ten key tiger reserves in the Central Indian and Western Ghats landscapes. The highest priority sites in Central India should include Sariska, Satpura, and Melghat Tiger Reserves (Figure 2), while Anamalai, Anshi-Dandeli, and Sathyamangalam Tiger Reserves are priority sites in the Western Ghats (Figure 3). Secondary priority should be given to Achanakmar, Indravati, Nagarjuna Srisailam, and Udanti-Sitanadi Tiger Reserves. Notably, these reserves are home to 19–56 villages within their core areas, which underscores the need for carefully managed human-wildlife coexistence to support tiger conservation and community livelihoods (Figure 2).

Site Level Prioritization

The present study showed that ruggedness and human disturbance significantly influenced the breeding and spatial dynamics of tigers in Sariska (Adjusted R2: 0.9953, P Value: 0.047; Table 1 and 2). While ruggedness was positive, human disturbance negatively influenced tiger breeding. Terrain complexity appeared to have masked human disturbance at some breeding sites. For example, tigresses have littered and used areas despite being very close (>1 km) to the highway and surrounded by villages owing to terrain complexity (Reddy *et al.*, 2019). Based on the suitable areas for breeding, we prioritize two blocks consisting of 6 villages for relocation to achieve optimum conservation success in creating inviolate space for tiger breeding and population recovery (Figure 4).

Discussion

MoEFCC's annual budget for 2023-24 was 2030.2 million USD, of which 0.03% (0.62 million USD) was allocated for big cat conservation. Since the available annual budget flow is much less than required, prioritization is urgently needed for optimum conservation success. Our study provides policymakers with a roadmap for optimizing village relocation using conservation resources.

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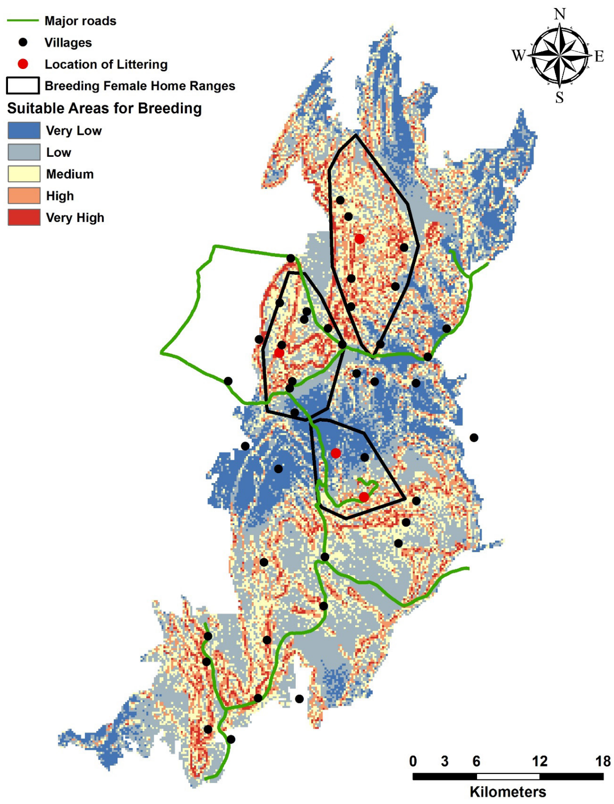

Figure 4: Breeding patch suitability of tigers in Sariska Tiger Reserve

Table 1: Details of top six multiple linear regression models to explain factors influencing the breeding of tigers in Sariska Tiger Reserve

Models	df	AIC	δAIC
bred~age+hum+road_dist+vill_dist+rugg	7	-25.99	0
bred~hum+road_dist+vill_dist+prey+liv	7	-18.05	7.94
bred~age+hum+road_dist+vill_dist+prey	7	-13.91	12.08
bred~hum+vill_dist+prey	5	9.14	35.13
bred~hum+road_dist+vill_dist	5	18.26	44.25
bred~hum+road_dist+vill_dist+liv	6	20.16	46.14

Dependant Variable: bred [Breeding or Non-breeding [(0/1)]
Abbreviations: hum: Human Disturbance, road_dist: Distance to Road, vill_dist: Distance to Village, rugg: Ruggedness, prey: Prey Availability, liv: Livestock Grazing Pressure

Treves & Karanth (2003) argued that voluntary resettlement is an extreme form of zoning that has been employed since the 1960s in India to move human settlements out of large carnivore habitats such as lions and tigers. Such a zoning approach has successfully reduced conflict and recovered carnivore and herbivore populations at many sites (Karanth, 2002; Karanth & Madhusudan, 2002; Harihar *et al.*, 2009). Recently, many conflict cases have been reported due to the high human-animal interface.

Table 2: Result of multiple linear regression to explain factors influencing breeding of tigers in Sariska Tiger Reserve

	β Estimate	Standard Error	t value	P Value	
(Intercept)	-1.1434	0.2473	-4.623	0.1356	
age	0.3064	0.1027	2.982	0.206	
hum	-1.0787	0.1096	-9.839	0.0645	.
road	-0.8454	0.1628	-5.192	0.1211	
vill	-1.4123	0.2107	-6.704	0.0943	.
rugg	4.1764	0.231	18.081	0.0352	*

Dependant Variable: Breeding or Non-breeding [(0/1), bred]
Model: Intercept, age, hum (Human Disturbance), road_dist (Distance to Road), vill_dist (Distance to Village), rugg (Ruggedness)
Residual standard error: 0.0368 on 1 degrees of freedom
Multiple R-squared: 0.9992, Adjusted R-squared: 0.9953
F-statistic: 253 on 5 and 1 DF, P-value: 0.04769

In the last five years, from 2019-2023, 349 people have died in tiger attacks in India. The number of deaths has been increasing, with 2022 recording the highest number of fatalities with 112. In India, state and central governments compensate for mitigating losses from tiger-related conflicts, covering human deaths, injuries, and crop damages. The National Tiger Conservation Authority (NTCA) supports states financially, with compensation amounts varying by state. For example, Maharashtra and Madhya Pradesh offer higher compensations for fatalities and injuries, recognizing the increased tiger-human interactions in their regions. This compensation policy aims to foster positive community relations and support conservation efforts by reducing financial impacts on affected families. Continued human-animal conflict causes economic losses and may reduce support for tiger conservation. Resettlement of villages from inside the two prioritized landscapes will minimise conflict and increase tiger numbers at the national level concurrent with our national goal.

Although the Central Indian tiger conservation landscape complex sustains 39% of the Indian tiger population in contiguous forests (Qureshi *et al.*, 2023), human pressure inside core areas of the tiger reserve is highest. This landscape has 60% of the total villages inside the core areas of the tiger reserves. Western Ghats tiger landscape complex sustains the highest concentration of tigers (29.52 % of the Indian tiger population) in contiguous forests worldwide (Qureshi *et al.*, 2023). Walston *et al.* (2010) advocated protecting source sites embedded in the larger permeable tiger landscape in their 6% solution. However, carnivore extirpation from core areas in densely populated South Asia is caused by large-scale habitat and prey loss driven by complex socio-cultural, economic and political factors (Tilson *et al.*, 2001). At least 40% of the tiger prey are classified as threatened on the IUCN Red List and 50% are declining (Wolf & Ripple 2016). Tiger abundance is strongly correlated with prey density across India (Karanth *et al.*, 2004). Tiger populations can persist in higher densities (7.3 – 21.7 tigers/ 100 km^2) for a long time if prey densities are high (56 ungulates/ km^2) (Karanth *et al.*, 2006). While Karnataka has done a commendable job of village relocation to secure its tiger core habitats (Muthanna *et al.*, 2014; Karanth *et al.*, 2018), efforts of the same magnitude are absent in neighbouring states.

Melghat and Satpura are part of the Satpura-Maikal landscape, considered the global priority tiger conservation landscape (Dinnerstein *et al.*, 2006). Additionally, Melghat has been identified as one of the 42 global tiger source sites and forms part of a large meta-population with Satpura, Pench, Bor, and Tadoba, which is very important for long-term tiger conservation (Yumnam *et al.*, 2014). Satpura and Melghat both have comparatively low tigers (50 and 57) and prey with large core areas (1339.26 and 1500.49 km², respectively) (Habib *et al.*, 2023; Qureshi *et al.*, 2023). Melghat is characterized by high human disturbance and overgrazing (Jhala *et al.*, 2015). The second priority list consists of Indravati TR, Nagarjun Srisilam TR and Udanti-Sitanadi TR. These tiger reserves have low tiger and prey density and high human disturbance. They are situated in the Red Corridor and are affected by left-wing extremist activity (Qureshi *et al.*, 2023). However, Indravati and NSTR hold vast stretches of forested lands (~3000 km²), different from any other tiger reserve in India.

Anshi-Dandeli, Sathyamangalam and Anamalai Tiger Reserve in the Western Ghats complex require immediate efforts to secure core tiger habitats. Sathyamangalam is part of the connected tiger reserves and protected area complex of Nagarhole-Bandipur-Mudumalai-Waynad-BRT and Sathyamangalam, which supports the largest tiger population (1087 tigers) in the world (Qureshi *et al.*, 2023). While all the other reserves in this world (Qureshi *et al.*, 2023). While all the other reserves in this protected area complex support a very high density of tigers (7.72 – 11.50 tigers/ 100 km²), the tiger density of Sathyamangalam is low (4.42 tigers/ 100 km²) (Fig protected area complex support a very high density of tigers (7.72 – 11.50 tigers/ 100 km²), the tiger density of Sathyamangalam is low (4.42 tigers/ 100 km²) (Figure 2).

Although all these tiger reserves have low tiger density, they can recuperate if human disturbance is minimized. Recent seminal work suggests that the tiger and their prey population can recuperate following relocations, consequently reducing grazing pressure and competition (Harihar *et al.*, 2009; Madhusudan, 2004). Harihar *et al.* (2014) advocated for targeted prey recovery strategies, citing their findings that inviolate PAs support the highest prey density than PAs with settlements or multiple-use forests. Prey population recovery and habitat improvement at these sites will help the population recovery of this resilient species, tiger. Tiger population recovery at these source sites will have landscape-level conservation implications for long-term tiger conservation.

Our site-level analysis showed that optimum conservation success could be achieved by relocating six out of 29 villages using 26% of the required budget. Relocating these villages is crucial to creating more inviolate space for tiger breeding in Sariska. Although Sariska's potential tiger-carrying capacity is higher than the current population of tigers, the relocation can help accumulate more tigers for the long-term conservation of this isolated tiger resource.

Way Forward

Conservation-related resettlements have been practiced in India since the 1960s (Rangarajan & Sahabuddin 2006). However, social scientists have criticized and considered the practice ineffective (Karanth 2007). While conservation biologists presented evidence of animal population recovery following resettlements (Karanth, 2002; Karanth & Madhusudan, 2002; Harihar *et al.*, 2009; Madhusudan, 2004), documented success of resettlements with forest dwellers is rare (Karanth, 2007). Conservation-related resettlements in densely populated South Asia have been suggested as the only conservation tool in the recent future (Karanth 2002). Karanth (2007) suggested that relocation can be used as a viable conservation tool provided it is socially justified, with adequate financial support and active consultation with stakeholders. Given the sensitive nature of the complex socio-cultural and political aspects involved, scientific assessment of necessity should be assessed at the site level.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

DATA AVAILABILITY

Data available from the corresponding author on request.

AUTHORS' CONTRIBUTION

BH and DM conceived the ideas and designed the methodology; DM analysed the data with inputs from BH, PN and PM; DM & BH led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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