



Conservation-induced resettlement as a driver of land cover change in India: An object-based trend analysis



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ABSTRACT

Located in the foothills of the Indian Himalaya, Rajaji National Park was established to protect and enhance the habitat of the Asian elephant (*Elephas maximus*) and tiger (*Panthera tigris*). In 2002 the Van Gujjars, indigenous forest pastoralists, were voluntarily resettled from the Chilla Range (an administrative unit of Rajaji National Park) to Gaidikhata, a nearby area where they were granted land for agriculture. In this study we used a variety of remote sensing approaches to identify changes in land cover associated with the resettlement. The methods comprise two main approaches. First, we used object-based image analysis (OBIA) to identify the pre-resettlement land cover classes of use areas (representing agricultural expansion and adjacent areas of grazing, and collection of fuelwood and fodder) and recovery areas (representing areas where settlements were removed, and the adjacent areas of resource use). Secondly, we used trend analysis to assess the gradual and abrupt changes in vegetation that took place in use and recovery areas. To conduct the trend analysis we used BFAST (Breaks For Additive Season and Trend), which separates seasonal variation from long-term trends, and identifies breaks that can be linked back to disturbances or land cover changes. We found that the OBIA classification yielded high average class accuracies, and we were able to make class distinctions that would have been difficult to make using a traditional pixel-based approach. Pre-resettlement, the recovery areas were classified as mixed forest and riparian vegetation. In contrast, the use areas were classified primarily as grass dominated, brush dominated, and plantation forest, and were located relatively far away from riparian areas. Following the resettlement, the trend analysis showed a sudden change in the seasonal variation of NDVI in areas converted to agriculture. Areas neighboring the new agricultural land experienced sudden decreases in NDVI, suggestive of disturbances, at a higher rate than the same land cover types elsewhere. At the same time, these neighboring areas experienced a gradual overall increase in NDVI which could be caused by an expansion of leafy invasive shrubs such as *Lantana camara* in areas heavily used for biomass collection. The recovery areas also experienced a gradual increase in NDVI as well as sudden breaks to this trend, but we lacked evidence to connect these changes to the resettlement. Our findings support the claim that the resettlement has shifted pressure from more ecologically valuable to less ecologically valuable land cover types, and suggest that to some degree resource use pressure has increased outside the park. The study employs a novel synthesis of OBIA and trend analysis that could be applied to land change studies more broadly.

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1. Introduction

1.1. Conservation-induced resettlement

India has a wide network of protected areas (PAs) that includes national parks, wildlife sanctuaries, conservation reserves and community reserves and covers close to 5% of its land area (Lasgorceix & Kothari, 2009). As many as 5 million people live

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within India's PAs, while up to 147 million people live nearby and are dependent on resources extracted from PAs (Karanth, 2007; Lasgorceix & Kothari, 2009). People in and around PAs engage in many activities that directly influence forest ecosystems, such as wood collection, livestock grazing, and harvesting of non-timber forest products (Shahabuddin & Prasad, 2004). Pressure on PA forests also comes from demand from urban centers, commercial forestry operations, mines, and commercial tourist operations (Rangarajan & Shahabuddin, 2006).

To reduce the impacts from human habitation and forest resource extraction, many PAs have relocated communities from inside to outside the PA, a politically contentious process known as conservation-induced resettlement. Conservation-induced resettlement is a globally uneven phenomenon, with reported cases drawn most intensively from Africa, South and South East Asia and North America (Brockington & Igoe, 2006). In the western United States and East Africa, colonial land and wildlife management practices included the forceful removal of native populations to create national parks (West, Igoe, & Brockington, 2006; see also Merchant, 2005; Neumann, 1998; Spence, 1999). In South Asia, displacement was also employed for protection of timber reserves under the forestry laws and practices of the British Raj (Rangarajan & Shahabuddin, 2006).

In India, conservation-induced resettlement is authorized under the Wildlife Protection Act of 1972, which allows the Forest Department to designate areas where human settlements were forbidden in order to protect specified flora and fauna (Quereshi & Moosvi, 2008, chap.9). A 2005 review by the government-appointed Tiger Task Force reported that 4594 families have been resettled in India since 1973 (Government of India, 2005); others estimate that the number is 15,000–20,000 families (Lasgorceix & Kothari, 2009). Resettlement from PAs has often been problematic, resulting in impoverishment, political disempowerment, and social dislocation (Agrawal & Redford, 2009; see also Brockington & Igoe, 2006; West et al., 2006 and special issues of the journal *Conservation and Society* in 2006 and 2009). In response to such negative outcomes, and following the poaching of the last tigers from Sariska National Park, several recent pieces of legislation attempt to improve the success of resettlement by making it voluntary in most instances.¹

The relationship between population and land degradation is often assumed to be a simple one, with population directly correlated to pressure on natural resources (Ives & Messerli, 1989). However, the reality is more complex and the effects of population on land degradation can be severe or mild depending on land management practices (Paudel & Thapa, 2001). While many studies have evaluated how population growth relates to land degradation (Warren, 2002), fewer have focused on effects of population decline. A study in Nepal found that outmigration from a watershed was associated with increases in vegetation cover and invasive species (Jaquet et al., 2015). It is important to assess the land impacts of conservation-induced resettlement as it has elements of both population decline and growth.

1.2. Resettlement of the Van Gujjars from Rajaji National Park

The western Terai Arc Landscape (TAL) is the forested lowland foothills of the Himalayas and has been designated as global

priority tiger conservation landscape by the World Wildlife Fund and Wildlife Conservation Society (Dinerstein et al., 2006). Historically dominated by tropical dry deciduous species such as *Shorea robusta*, the forests of the TAL in northern India have come under tremendous pressure from local communities. A case in point is the Van Gujjar communities (forest Gujjars), traditionally indigenous pastoralists who live throughout the TAL. The Gujjars have a long history of marginalization, weak legal standing, and unequal treatment (Gooch, 2009). Gujjars formerly migrated between the foothill forests and alpine meadows of the Himalayas. However, due to legal conflicts over land use, the Gujjars now live year-long in the foothill forests, increasing the pressure on those forests and riparian areas (Harihar & Pandav, 2012). In many places the Gujjars are given permits to cut grass and lop trees for fodder, activities that create forest openings which are then colonized by invasive weeds such as *Parthenium hysterophorous* (Gajar grass) and *Lantana camara* (Lantana) (Joshi, 2009). Grazing buffalo also foul water holes and degrades the native tall grasslands adjacent to the dry washes (*raus*) (Joshi & Singh, 2009).

While conservation-induced resettlement is not yet widespread in the TAL, more than 1000 families have been voluntarily relocated away from one ecologically valuable area: Rajaji National Park (Harihar, Ghosh-Harihar, & MacMillan, 2014). Located within the Indian state of Uttarakhand, Rajaji National Park was established in 1984 to protect and enhance the habitat of the Asian elephant (*Elephas maximus*) and tiger (*Panthera tigris*). In April 2015, the PA core zone and parts of the buffer zone were additionally declared as the Rajaji Tiger Reserve and listed as the 48th reserve under Project Tiger (Rawat, 2015). The park also holds extensive habitat for native megafauna such as Goral (*Nemorhaedus goral*), golden mahseer (*Tor putitora*), chital (*Axis axis*), and leopards (*Panthera pardus*). Extensive forest has been lost to development projects surrounding the park, such as road and rail expansion, hydropower, the resettlement of people displaced by the Tehri dam, and the creation of an army cantonment (Nandy, Kushwaha, & Mukhopadhyay, 2007). When the park was first created, 512 Gujjar families lived within the park. By 1998 that number had grown to 1390 families, each owning an average of 15–17 buffalos and dependent on selling milk for 89% of their total income (Harihar et al., 2014; Sinha, 2006).

By 2004, a total of 688 families were resettled to Gaindikhata, including all 193 families from the Chilla Range (Mishra, Badola, & Bhardwaj, 2007; Rasaily, Rawat, Chandola, & Sharma, 2012). At Gaindikhata, families were moved to the *basti*, an area peripheral to the *Gaon* (village proper) (Fig. 1). Each family was given two acres for agriculture and 200 sq. meters for construction of *dehras* (traditional thatched buildings). Medical and veterinary services, irrigation facilities, and schools were provided as part of the resettlement package. Families were compensated approximately \$4000 per family. It was a difficult process for the resettled Van Gujjars to acquire services that have been afforded to other settled tribal peoples, such as voting rights and ration cards (Gooch, 2009; Singh, 2012). Nevertheless, perhaps due to the perceived success of the Rajaji relocation, a survey of 158 Gujjar households across the TAL showed widespread support for resettlement out of forested areas and into agricultural settlements (Harihar et al., 2014).

The resettlement appears to have yielded ecological benefits to the park. Field surveys following the resettlement have shown that wildlife in Rajaji National Park, including elephants, has expanded its range and that vegetation fodder has increased (Joshi & Singh, 2009). Elephants have been observed utilizing the whole of the forest area and water holes for routine activities throughout the day (Joshi & Singh, 2009). Tigers have also steadily increased in number in the region since the resettlement (Harihar et al., 2014). Ecological benefits to vegetation are less clear. A study of vegetation near the evacuated areas suggested that weed cover decreased and herb

¹ The 2006 Scheduled Tribes and Other Traditional Forest-Dwellers Act provided a mechanism for voluntary relocation while asserting a need to respect the rights of local people (Harihar et al., 2014; Sekhsaria, 2007). Similarly, modifications enacted in 2008 to the National Rehabilitation and Resettlement Policy stated that resettlement out of PAs should be voluntary (Lasgorceix & Kothari, 2009).

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