



## **Navigating fragmented landscapes: pastoralism and dependence on open natural ecosystems in western India**

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**Key words:** land use, movement, pastoralism, deccan peninsula

### **Abstract**

Open Natural Ecosystems (ONEs) cover about 10% of India's geographical area and are extremely fragmented. Sustainable use of ONEs for low-input livelihoods like extensive pastoralism requires an understanding of the nature of the dependence of pastoralists on these native habitats. This is especially crucial in India where such socio-ecological systems lack recognition and are classified as 'wastelands' in policy and legislation. We tracked livestock movement in different land uses of western India's ONEs for 109 days between 2022-2023. We used non-participant observations and interviews with pastoralist men and women to understand movement-related decision making. Based on simple linear models and availability vs use frameworks, we infer pastoralism's fine-scale use of the landscape. Livestock movement patterns show that pastoralist dependence on ONEs at higher elevations is highest in the monsoon (use is >2.5 times the availability of ONEs), and the availability of irrigation, household labor, and social networks determines this movement. Pastoralism in this region is heavily influenced by the availability of agricultural residues and farmer decisions contrary to the popular understanding, some households appear to benefit from irrigated agriculture. Despite rapid land transformations, however, pastoralism remains a low-input and economically lucrative livelihood that allows seasonal use of savanna ecosystems. Our findings contribute to understanding of how these ONE-based livelihoods navigate land use change and offer insights into the potential of community-led ecosystem management.

### **Introduction**

Globally, India does not figure as a country with extensive rangelands and 'grazing-only' systems because of the wide presence of socially complex small-scale farming systems (Godde et al. 2020; Herrero et al. 2017) and hence is a data-deficient region in global analyses on rangeland management (Godde et al. 2020). However, 10% of India's geographical area is covered by Open Natural Ecosystems (ONEs) which are naturally occurring grass-dominated landscapes in semi-arid and arid regions of India (Ratnam et al. 2016). These consist of ecosystems like deserts grassy to mesic savannas, ravines, and rocky outcrops (Madhusudan & Vanak 2022). Like many other regions of the world, India has a significant population of extensive pastoralists who practice large and small livestock rearing by relying on ONEs for some parts of the year. Extensive pastoralism is a specialized method of rearing livestock in semi-arid regions that relies on movement between geographies to benefit from the fluctuation of water and biomass availability (FAO 2021). Although the contribution of this system to India's food security

and economy is being formally investigated, some estimates suggest that 53% of India's milk production and 74% of India's meat production comes from extensive pastoralist systems (Kishore & Kohler-Röllefson 2020).

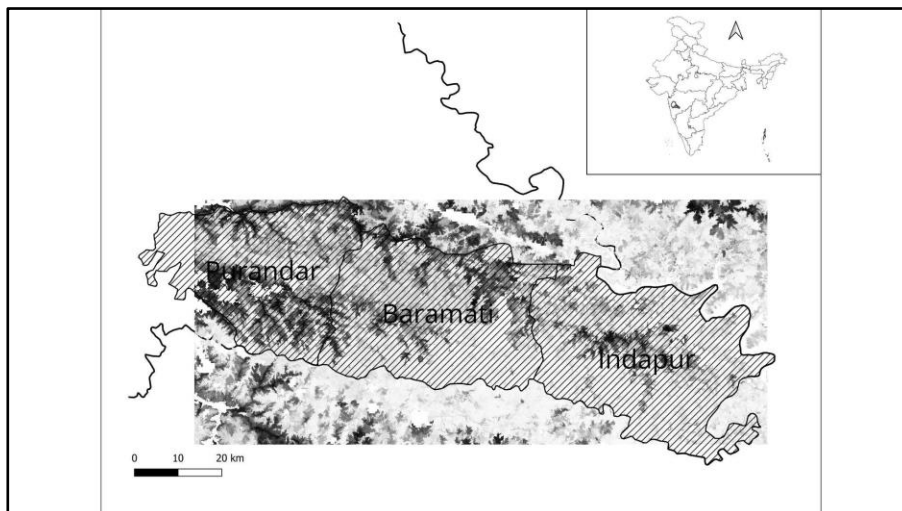
Land use diversion in ONEs, especially towards year-round agrarian production, is a well-known phenomenon. About 14.8 million ha of grasslands and shrublands have been converted to croplands in the 20th century and this conversion was especially faster post-1960s (Tian et al. 2014). Currently, ONEs are extremely fragmented, so much so that 94% of ONE patches are now only between 1-100 hectares (Madhusudan & Vanak 2022). With these high levels of fragmentation in ONEs, livestock management systems and associated institutions regulating access have further gone to the margins. Additionally, since India is not a typical extensive rangeland system (i.e. with low human population densities, dry climate & low ease of farming), livestock production systems are viewed as only supplementing agrarian livelihoods. However, at least 13 million pastoralists practice specialized forms of livestock keeping dependent on some level of mobility (Kishore & Kohler-Röllefson 2020). Hence, it becomes imperative to understand the nature of dependence and seasonal use of lands for pastoralism from the perspective of pastoralists' response to the fragmentation of ONEs.

Research on land use and pastoralist mobility from other parts of the world has shown that fragmentation causes disenfranchisement. Burnsilver et al. in Galvin et al. 2008 record how the Maasai in the Amboseli landscape, due to land fragmentation were pushed to opt for intensification of husbandry practices in smaller areas that included rearing poorly adapted hybrid cattle in arid regions. Groups of pastoralists like the Samburu, Turkana, Fulani, and Sahelian pastoralists have all been affected by some form of fragmentation (Galvin et al. 2008) bringing about changes in the way they move in the landscape and their socio-economic conditions. Butt 2014 describes a case of functional fragmentation where the creation of parks for wildlife conservation has affected how the Maasai move. He shows how new land tenure arrangements because of conservation parks has 'co-produced' the phenomenon of 'cattle incursions'. Another important form of functional fragmentation, albeit not from an arid or semi-arid savanna is the case of the Gaddi pastoralists in Himachal Pradesh. Ramprasad et al. 2020 note how afforestation activities, along with changing plant species composition, has threatened pastoral livelihoods by reducing fodder availability and forcing a change in migratory routes. However, contrary to the literature on disenfranchisement, there is also growing evidence from Africa which shows that commonages which were fragmented are also being brought back under management for pastoralism through both top-down and bottom-up tenurial arrangements (Bollig & Lesorogol 2016). However, India remains a blindspot in understanding responses of pastoralists to fragmentation.

## **Methods**

### ***Study site***

We chose to work in the Pune district of western Maharashtra because of the presence of a considerable pastoralist population and fragmented ONEs. We specifically focused on pastoralist villages in four talukas - Purandar, Daund, Baramati & Indapur (Map 1; QGIS 3.34.13). The land cover in these 4 tehsils is a mix of ONEs (grasslands, rocky habitats, inselbergs, and scrub vegetation), irrigated and dry-land agriculture, industrial/urban areas, and rural settlements. Concerning land tenure, the ONEs in the study area are largely uncultivated private lands, followed by those managed by the Forest Department and as village commons. The region receives an annual rainfall of between 800-1200 mm.



Map 1: The above map shows the location of the study area in India. Darker the color, higher the possibility of that pixel being an ONE.

### **Data collection**

We tracked livestock movement in different land uses of the study area for 69 days in the monsoon of 2022 and 40 days in the summer of 2023 (a total of 109 days) to understand seasonal movement patterns. We used handheld GPS devices and low-cost custom-made GPS trackers to map livestock movement where we recorded time spent in each land use by the herd (Butt et al. 2010, Wade et al. 2024). In these walk-along movement tracking surveys, we used non-participant observations of pre-herding, post-herding, and herding activities of 74 pastoralist households (both women and men) to understand movement-related decision making. We used semi-structured interviews to collect data on household socio-economic characteristics to understand dependence on pastoralism and test for relationships with movement patterns (Salamula et al. 2017; Jones et al. 2022).

### **Analysis**

For the movement data, we used the spatial points downloaded from the GPS devices, to perform a use vs. availability analysis on land cover. Land cover information was extracted from the Dynamic World V1 10 m resolution raster available on Google Earth Engine (Brown et al. 2022). From this, we inferred whether pastoralists selected for specific land covers seasonally based on what was available for them. Since pastoralists could move, we considered the ‘available’ land cover as those in all 3 administrative units of our study area. We then used simple linear regressions to test for relationships between household socio-economic characteristics and movement patterns (Rstudio 2023.06.2). Lastly, using axial and open coding (Corbin & Strauss 1990), we analysed notes from our field observations on decision-making around movement and living experiences of herding livestock in ONEs and agricultural landscapes.

### **Results**

We collected data of 75 households from 26 pastoralist settlements, out of which 70 households belonged to the Dhangar group of pastoralists and 5 were from other groups. Because we focused on herding activities, there was a gender and age bias within our pool of respondents since this demographic tended to herd livestock more often than others. Out of 75 households we interviewed or observed activities of, 64 were that of pastoralist men, 46% of whom were within 21-40 years of age. For the rest of the 10 households, 5 were women herders and 6 were pairs of men & women from the same household who were herding together.

Neither daily distance traveled seasonally nor annual migration patterns were dependent on herd sizes kept by a household (Adjusted  $R^2=0.006$ , effect size  $=-0.008$ (SE=0.006); Adjusted  $R^2=0.094$ , effect size

=0.004(SE=0.001)). However, herd sizes were strongly predicted by the number of people in the household who were engaged full-time in pastoralism and agricultural activities (Adjusted  $R^2=0.443$ ; Figure 1). More specifically, with every additional member in pastoralism, 32 additional livestock heads could be reared on an average while with every additional member in farming, the herd size was reduced by 14 heads on an average.

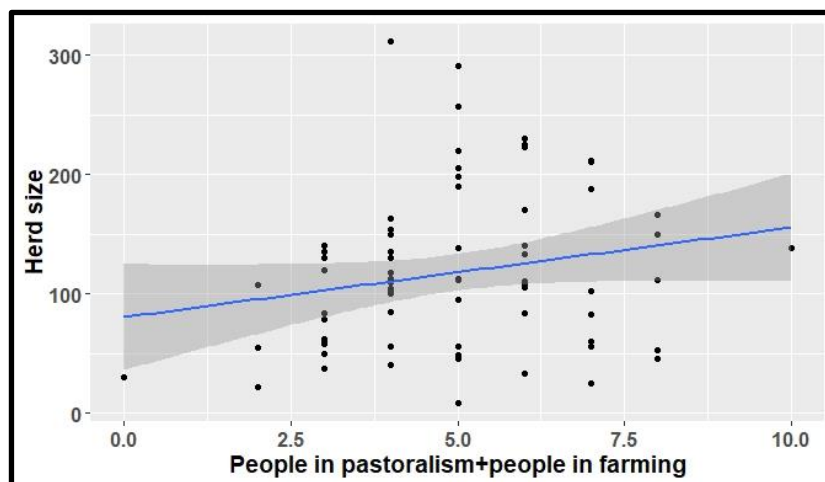


Figure 1: A linear model showing the relationship between the number of people in the household who were engaged full time in pastoralism and farming and the herd size kept by the household.

Fine-scale livestock movement patterns, when looked at from a use vs. availability analysis, show that pastoralist dependence on land covers like grass & scrub (which form ONEs) is highest in the monsoon (the frequency of their use is 2.5 times higher than their availability; Figure 2). Additionally, pastoralist households travel less in the monsoon compared to dry seasons (~ 7 km lesser on an average).

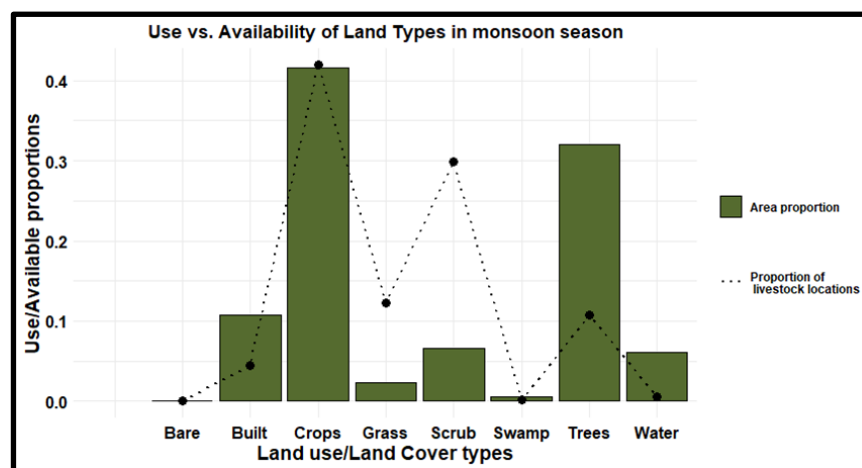


Figure 2: The bars in the above graph indicate the proportion of available land covers while the dotted lines indicate the proportion of spatial points that fell in that land cover in the monsoon season.

More than 80% of the households accessed only private fallow lands during both seasons (Figure 3).

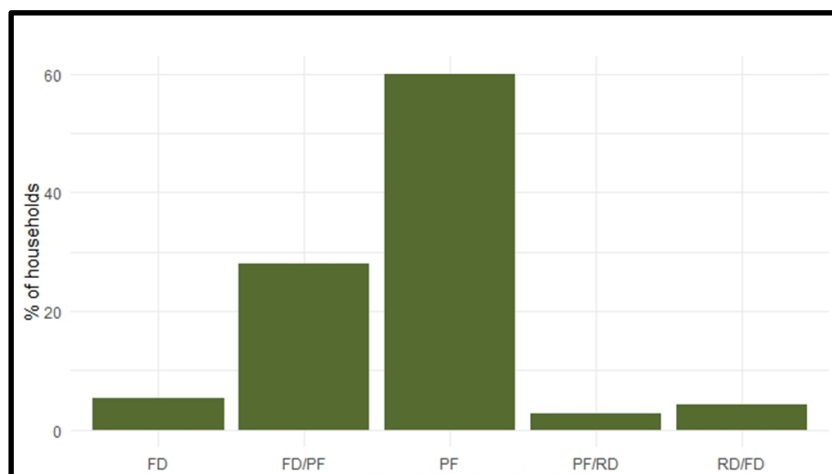


Figure 3: The bars in the above graph indicate the proportion of daily tracks in different land tenures. (FD=reserve forests, PF=private fallows, RD=Revenue department lands)

The presence of irrigation and farmer decisions determined the accessibility of lands for pastoralists. Households accessed fodder in both seasons based on interpersonal relations and social networks with farmers. Access to reserve forests was also based on informal understanding with the lower rungs of the forest bureaucracy, which often also resulted in conflicts. Because of the fragmented nature of village common lands, they were rarely sufficient for multiple pastoralist herds and thus, very few households relied on them consistently throughout a single season.

### Discussion

Seasonal differences in daily distance traveled by pastoralists was expected because biomass needs are met more easily in the monsoon due to the proximity of ONEs. However, contrary to our understanding, we found poor evidence for the relationship between herd sizes and daily travel patterns as well as long distance migration patterns. Additionally, private fallow lands seemed overwhelmingly important for pastoralism in this landscape. We conclude that availability of household members and increasing social networks with farmers enabled pastoralists to navigate changing land use. This finding offers a different perspective from the more common understanding of pastoralist-farmer relations centered on conflict (Usman and Nichol, 2022; McGuirk & Nunn, 2024). We argue hence, that pastoralism needs to be viewed as a livelihood embedded in an agrarian landscape in this region of India. This is because dispersed household decisions in the landscape around the cultivation of land is determining land availability for pastoralists.

We also find that ONEs are extremely important for pastoralists in the monsoon. However, the process of ‘commoning’ or creation and strengthening of institutions managing commons is not adequate for livelihood security of pastoralists in this region (Bollig and Lesorogol, 2016). Instead, securing the agriculture-pastoralism nexus through institutions appears to be more beneficial for pastoralism.

Lastly, we provide evidence that ONEs in this region of India are supporting livestock production seasonally. However, land diversions in ONEs are assumed to have minimal impact on people and ecosystems. That is the reason that these lands are termed ‘waste’ (DoLR 2019) and demarcated for diversion. For eg. almost 60% of ONEs in Maharashtra are demarcated for potential afforestation (Madhusudan and Vanak 2022). Our findings help to develop a nuanced understanding of the nature of dependence of livestock-based livelihoods on ONEs in a rapidly modifying landscape.

## Acknowledgements

We would like to thank the Rufford Foundation, UK and the Centre for Pastoralism, India for the financial support they provided for field work. We would also like to thank Ms. Ashwini Labde, Mr. Hrishikesh Karandikar and Mr. Shivam Shinde for their contributions to data collection. We obtained ethics approval from both- Human Research Ethics Committee and the Animal Research Ethics Committee of ATREE, Bengaluru in 2021 before carrying out this research work.

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