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Influence of Terrain on the Distribution of Indian Wild Ass, Equus hemionus khur, in the Great Rann of Kachchh, Gujarat, India

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Abstract

This study evaluated the influence of terrain on the distribution and habitat selection of the Indian Wild Ass (*Equus hemionus khur*) in the Great and Little Rann of Kachchh, Gujarat. Using a two-phase field design involving systematic transects (n = 41) and structured sampling (n = 210), species occurrence was assessed across flat, undulating and rough terrains. Results showed a strong preference for flat terrain (P = 0.82; Wi = 1.72), while undulating and rough terrains were used marginally or avoided. Chi-square analysis confirmed a significant association between terrain and occurrence ($\chi^2 = 61.44$, $p < 0.001$). Herd size was highest in flat areas (mean ≈ 33) and declined with increasing terrain complexity. Logistic regression further supported terrain as a key predictor of occurrence (AUC = 0.89), with slope negatively influencing suitability.

Introduction

The genus *Equus* (horses, asses, and zebras) is strongly associated with open habitats across Africa and Asia (Moehlman, 2002a, b). The Przewalski's horse (*Equus ferus przewalskii*) inhabits the steppes and semi-deserts of Central Asia (Van Dierendonck & de Vries, 1996; King & Gurnell, 2005; Wakefield et al., 2019), while the African wild ass (*Equus africanus*) occurs in the arid and semi-arid deserts of the Horn of Africa and shows strong adaptations to heat and water scarcity (Kebede, 1999; Moehlman, 2002c). Zebras, including the plains zebra (*Equus quagga*), are distributed across African savannas and exhibit seasonal movements driven by rainfall and forage availability (McNaughton, 1985; Bodenstein et al., 2000). Overall, all *Equus* species depend on open landscapes that facilitate visibility, social behaviour, and efficient movement, although each is ecologically specialized to its environment (Rubenstein, 1986; 2010 & 2015). The Indian Wild Ass (*Equus hemionus khur*) is the only surviving Asiatic wild ass in India and is largely restricted to the Rann of Kachchh, with core populations in the Little Rann and seasonal dispersal into parts of the Great Rann (Ali,1946; Shah, 1993, 1996 & 2004; Singh, 2000; Jhala et al., 2008).

Despite its presence across the broader Rann landscape, its distribution is highly localized, with field observations indicating a strong association with flat terrain. This observation led to the hypothesis that terrain structure plays a key role in determining habitat suitability. Although habitat use of the species has been documented in the Little Rann of Kachchh (Gee, 1963; Singh et al., 1999; Jhala et al., 2008; Sen et al., 2013; Singh et al., 2018; Verma, 2025), terrain-specific distribution patterns remain poorly understood. In this context, the present study was designed in two sequential phases to investigate how terrain influences the distribution, habitat selection, and spatial ecology of the Indian Wild Ass across the Rann ecosystem.

Study Area:
The study was conducted in the Great Rann of Kachchh and adjoining parts of the Little Rann of Kachchh, Gujarat, India. The landscape comprises saline flats, seasonal wetlands, and elevated *bets* (islands), forming a heterogeneous terrain from flat mudflats to undulating and rough or rocky surfaces.

Large salt-encrusted flats dominate the region, which are inundated during the monsoon and dry into hard saline crusts in the post-monsoon period. Scattered *bets* and vegetated fringes provide stable patches and enhance habitat heterogeneity (Merh, 2005). The climate is semi-arid with high seasonal variability. Summer temperatures often exceed 45–50°C, and average annual rainfall is about 300 mm, mainly during the southwest monsoon (Kumar et al., 2010; Joshi et al., 2017). Seasonal flooding, salinity, and long dry spells strongly influence soil, vegetation, and habitat conditions. Vegetation is sparse, mainly halophytic grasses and shrubs, with *Neltuma juliflora* occurring in relatively stable, less saline zones, especially on fringes and some *bets* (Merh, 2005; Joshi et al., 2017). For this study, the area was categorized into three terrain types: (i) Flat terrain: saline mudflats and gentle plains, (ii) Undulating terrain: *bets* and moderately elevated zones, and (iii) Rough terrain: irregular, rocky surfaces with strong micro-relief.

Materials and Methods

Study Design and Data Collection: The study was conducted in two sequential phases to assess the influence of terrain on the distribution of the Indian Wild Ass. Phase I involved exploratory surveys to generate baseline information on terrain use and identify initial occurrence patterns. Field data were collected using systematic transects and opportunistic sightings across three terrain types: flat, undulating, and rough. Geographic coordinates were recorded using handheld GPS devices. Since coordinates often represented observer positions rather than exact animal locations, site verification was performed by revisiting locations and confirming indirect evidence such as hoof prints. For each confirmed record, terrain type, vegetation availability (as forage proxy), water availability, human disturbance, and herd size were noted. A total of 41 transects (22 in fringe areas and 19 in bet regions) were established, each about 1 km long and spaced 20–25 km apart. Surveys were conducted in winter (December-February), summer (April-June), and post-monsoon (September-October) to capture seasonal variation. This phase yielded 150 independent sightings for terrain-wise analysis.

Terrain Characterization

GPS coordinates were used to extract terrain attributes from 30 m SRTM digital elevation models in QGIS. Slope was calculated and classified as flat (< 5°) and rough/undulating (> 5°). Elevation and slope variability were also derived. Terrain was categorized as flat (saline plains and gentle slopes) or rough/undulating (rocky and uneven surfaces with micro-relief).

Hypothesis-Driven Sampling

Based on Phase I results, a structured design was developed to test habitat differences across terrain types. A total of 210 sampling points were systematically distributed across flat, undulating, and rough terrains. At each point, species presence/absence and herd size (if present) were recorded along with vegetation condition, water availability, human disturbance, and terrain type. These observations were used to assess habitat use and develop a suitability framework ranging from highly suitable to unsuitable habitats.

Data Analysis:

Terrain-wise Distribution and Association Analysis

Phase I sightings (n = 150) were summarized to evaluate habitat use patterns, mainly comparing flat and rough terrain due to minimal observations in undulating areas. Association between terrain type and occurrence was tested using a chi-square (χ^2) test.

Habitat Selection Analysis

Habitat preference was estimated using Manly's selection ratio (Manly et al., 2002)

$$W_i = \frac{u_i}{a_i}$$

where u_i is habitat use proportion and a_i is habitat availability. Values > 1 indicate preference, = 1 proportional use, and < 1 avoidance.

Occurrence

Occurrence was calculated from Phase II as the proportion of presence records within each terrain category relative to total sampling points in that category, providing a field-based measure of habitat use.

Logistic Regression Modelling

A binomial logistic regression was applied with presence–absence as the response variable and terrain variables (slope and terrain category) as predictors. Model performance was evaluated using AUC (Area Under the ROC Curve).

$$\log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1(\text{Slope}) + \beta_2(\text{Terrain Type})$$

Results

Terrain-driven Distribution and Hypothesis Testing

This study was based on the hypothesis that the Indian Wild Ass is distributed across all major terrain types of the Rann without strong preference. To test this, a stratified sampling design was implemented across three terrain categories viz., flat, undulating, and rough, using 210 sampling points (100 flat, 60 undulating, and 50 rough).

Results clearly contradicted this assumption of uniform distribution. Species presence was recorded at 82 flat sites, 18 undulating sites, and 10 rough sites, corresponding to occurrence probabilities of 0.82, 0.30, and 0.20, respectively. This indicates a strong decline in occurrence with increasing terrain complexity, despite availability across all categories, suggesting selective habitat use rather than random distribution.

Table 1
Sample points and Occurrence

Terrain Type	Sample Points	Presence	Absence	Occurrence	Mean Herd Size
Flat	100	82	18	0.82	34.2
Undulating	60	18	42	0.30	16.5
Rough	50	10	40	0.20	12.8

To further validate this pattern, 150 independent sightings were analysed. Most observations (82%) occurred in flat terrain, while only 18% were recorded in rough areas, confirming a strong bias towards flat habitats. This distribution was not proportional to habitat availability, indicating that sampling effort alone does not explain the pattern. Chi-square analysis further confirmed a highly significant relationship between terrain type and occurrence ($\chi^2 = 61.44$, $df = 1$, $p < 0.001$). These results reject the hypothesis of equal use across terrain types and demonstrate that terrain is a key driver of habitat selection in the Rann ecosystem.

Table 2
Terrain-wise distribution of Indian Wild Ass sightings

Terrain type	Number of sightings (n)	Percentage	Mean herd size	Standard deviation
Flat terrain	123	82%	33.1	14.6
Rough terrain	27	18%	13.5	2.1
Note: Mean and standard deviation values are derived from the complete dataset (n = 150).				

Habitat Selection and Occurrence

Occurrence probabilities from Phase II sampling further highlight terrain-driven habitat use. Flat terrain showed a high occurrence probability (P = 0.82), while undulating (P = 0.30) and rough terrain (P = 0.20) recorded much lower values. This indicates that although the species may occur across all terrain types, its likelihood of presence decreases markedly with increasing terrain complexity. Ecologically, these values reflect observed (empirical) probabilities under high detectability conditions, supported by the species' large body size and open-habitat behaviour. Consistency between presence records and independent sightings further strengthens the reliability of this pattern.

Habitat selection ratios also confirm this trend. Flat terrain showed clear preference (Wi = 1.72), undulating terrain indicated near-neutral use (Wi = 1.05) and rough terrain showed avoidance (Wi = 0.84). Together, these results define a clear habitat hierarchy, where flat terrain represents optimal habitat, undulating terrain acts as transitional or marginal habitat, and rough terrain functions as suboptimal habitat.

Table 3
Habitat Selection Ratio (Manly's Index)

Terrain Type	Proportion Used (u_i)	Proportion Available (a_i)	Selection Ratio (Wi)	Interpretation
Flat	0.82	0.476	1.72	Preferred
Undulating	0.30	0.286	1.05	Neutral
Rough	0.20	0.238	0.84	Avoided

Herd Size Variation

Herd size showed a strong relationship with terrain type. In flat terrain, herd sizes ranged from 18 to 55 individuals (mean = 33.1 ± 14.6), whereas rough terrain supported much smaller groups of 12–15 individuals (mean = 13.5 ± 2.1). Phase II results showed a similar trend, with mean herd sizes decreasing from 34.2 in flat terrain to 16.5 in undulating and 12.8 in rough terrain. This pattern indicates that terrain influences not only occurrence but also social structure and group dynamics. Larger herds in flat areas are likely supported by open visibility, easier movement, and better group cohesion. In contrast, rugged terrain may create physical constraints, reduce forage accessibility, and hinder coordinated movement, thereby limiting herd formation and resulting in smaller group sizes.

Spatial Distribution Patterns

The spatial pattern of sightings showed strong clustering in flat terrain across the Rann ecosystem. High-density records were consistently observed in flat areas such as Gadka bet, Bhojardo, and Nadabet, whereas rough terrain locations like Dholavira and Tragadi bet supported comparatively fewer individuals. Importantly, no sightings were recorded from highly undulating or hilly zones in parts of the Great Rann, indicating near-complete avoidance of such habitats. This spatial segregation highlights terrain as a key limiting factor and suggests that some areas may act as ecological barriers rather than usable habitat.

Table 4
Selected field observations of Indian Wild Ass

SN	Location	Latitude (°N)	Longitude (°E)	Terrain	Herd Size
1	Gadka bet	23.8207	70.9947	Flat	55
2	Bhojardo	23.5617	69.8489	Flat	50
3	Mauvana	23.8200	70.9108	Flat	45
4	Nadabet	24.2550	71.1150	Flat	30
5	Rachhena	24.4417	71.3400	Flat	25
6	Samali	24.3817	71.3461	Flat	20
7	Dholavira	23.8947	70.2188	Rough	15
8	Khadir bet	23.8500	70.2500	Flat	22
9	Pachchham bet	23.9000	70.4500	Flat	18
10	Tragadi bet	23.7500	70.6000	Rough	12

Predictive Modelling and Terrain Influence

Logistic regression results further confirm the strong role of terrain in determining species occurrence. Slope showed a pronounced negative effect (β = − 1.12), indicating that increasing ruggedness reduces habitat suitability. Flat terrain was positively associated with occurrence (β = +1.85), whereas rough terrain had a negative effect (β = − 0.95). The model performed well in predicting occurrence patterns (AUC = 0.89), indicating that terrain variables alone explain a substantial portion of the observed distribution. This underscores terrain as a key ecological determinant capable of reliably predicting species presence even without additional environmental predictors.

Table 5
Logistic Regression Model Output

Variable	Coefficient (β)	Interpretation
Intercept	-0.45	Baseline condition
Slope	-1.12	Strong negative influence
Flat terrain	1.85	Strong positive association
Rough terrain	-0.95	Negative association

Discussion

Besides the present study, many other study reveal the spatial distribution of the species in flat areas (Shah and Qureshi, 2007; Barman et al., 2021). The results of the present study clearly indicate that

terrain is a major ecological factor governing the distribution of the Indian Wild Ass in the Rann ecosystem. The observed pattern shows a distinct and consistent preference for flat terrain, while undulating and rough terrains are used marginally or largely avoided. This deviates from the initial expectation of a more uniform distribution across available habitat types and highlights a clear case of habitat specialization.

The strong association with flat terrain can be explained by the species' cursorial adaptations. The Indian Wild Ass is morphologically and behaviourally adapted for sustained movement in open environments, where locomotion efficiency plays a critical role in survival. The extensive saline flats of the Rann provide optimal conditions for long-distance movement with minimal energetic cost, while also facilitating access to spatially dispersed forage and water resources (Barman et al., 2021). In addition, flat and open landscapes enhance visibility, which improves predator detection and supports coordinated herd behaviour, consistent with general equid ecological traits (Rubenstein, 1986).

In contrast, the reduced occurrence in undulating and rough terrain reflects clear ecological limitations. Increased surface irregularity likely imposes higher energetic costs, restricts movement efficiency, and reduces effective visibility. These constraints collectively lower habitat suitability, making such areas less frequently used. The near absence of records from highly rugged zones further suggests that these habitats act as ecological barriers rather than functional habitat within the landscape. Similar terrain-related restrictions on distribution have been reported in earlier studies from the Rann region (Prasad et al., 1994).

From a comparative perspective, these findings are consistent with habitat use patterns observed in other members of the genus *Equus*. Species such as the Przewalski's horse, African wild ass and plains zebra predominantly occupy open habitats including steppes, deserts, and savannas. This shared preference is closely linked to their similar morphological adaptations, particularly their specialized hoof structure. The single, compact hoof design characteristic of equids is well-suited for firm and open substrates, enabling efficient high-speed locomotion and effective weight distribution. Such adaptations are most advantageous in flat or gently undulating landscapes, where movement efficiency and predator avoidance are maximized.

The results demonstrate that flat terrain represents the primary ecological niche of the Indian Wild Ass in the Rann ecosystem, while undulating and rough terrains function as marginal or suboptimal habitats. These findings are consistent with earlier ecological assessments from Gujarat (Shah, 1993; Parasharya & Teli, 2015) and reinforce the role of terrain-driven habitat selection as a key determinant of spatial ecology in this species.

Conclusion

The present study demonstrates that terrain is a key determinant of the distribution and habitat use of the Indian Wild Ass in the Rann ecosystem. The species shows a clear preference for flat terrain, while undulating and rough areas are used minimally or avoided. This pattern is strongly supported by

differences in occurrence, herd size, spatial clustering, and predictive modelling results. Flat terrain provides optimal conditions for movement efficiency, visibility, and social cohesion, aligning with the cursorial adaptations of the species and other members of the genus *Equus*. The findings confirm that the Indian Wild Ass is a habitat specialist strongly dependent on open, flat landscapes, with terrain acting as the primary ecological driver shaping its spatial ecology in the Rann of Kachchh.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the applicable national and institutional guidelines for wildlife research. The study involved non-invasive field observations and ecological surveys, and no animals were captured, handled, manipulated, or subjected to experimental procedures.

Consent for publication Not applicable

Availability of data and materials

All data generated and analysed during this study were collected through field surveys conducted by the authors.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Sandeep Munjpara and Jigar Joshi conceived and designed the study, conducted field surveys, collected data, and analysed the data. Sandeep Munjpara and Jigar Joshi prepared the first draft of the manuscript. Amitkumar Nayak and B. P. Pati critically reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Figures

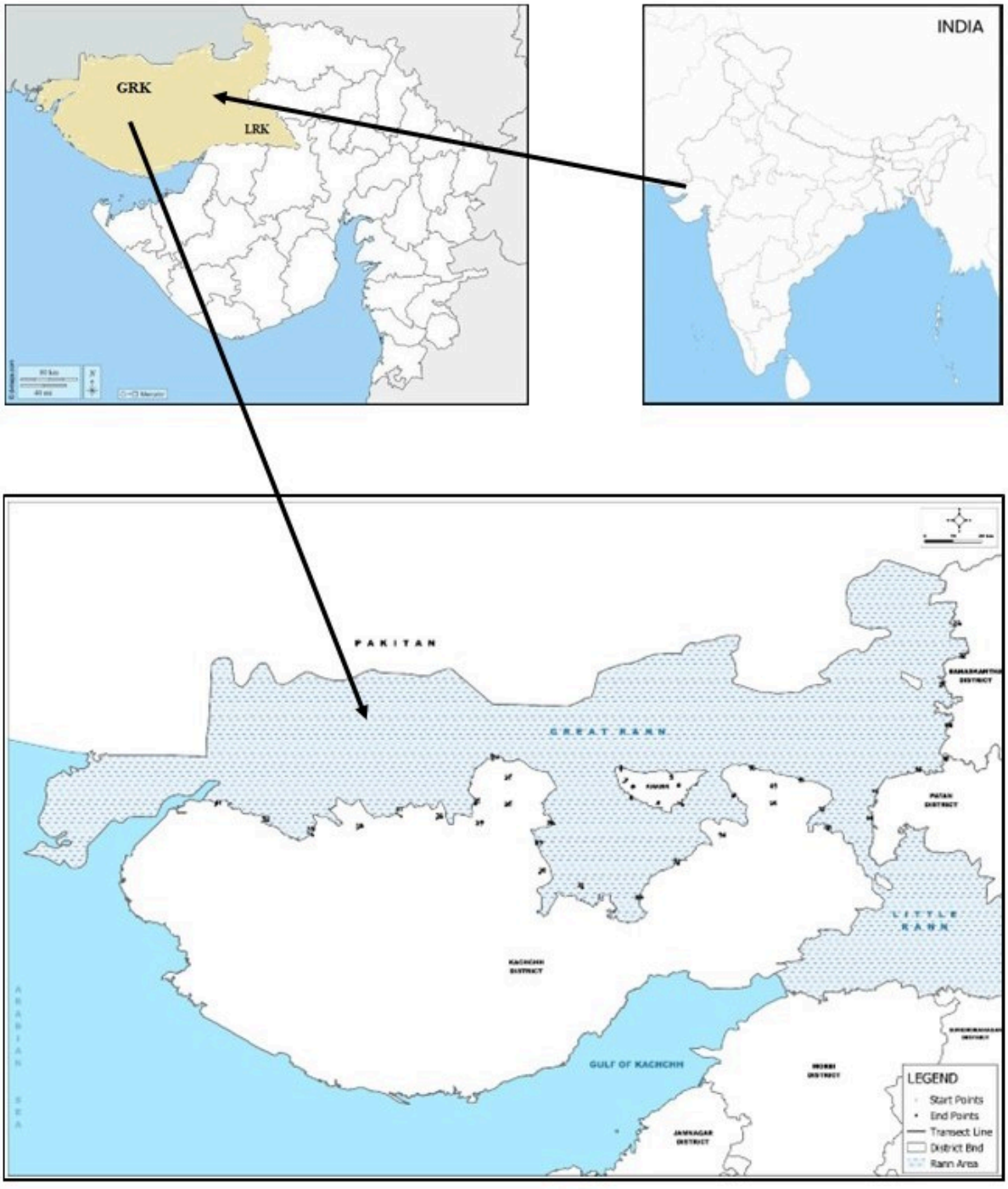


Figure 1

Study Area - Great and parts of Little Rann of Kachchh, Gujarat, India

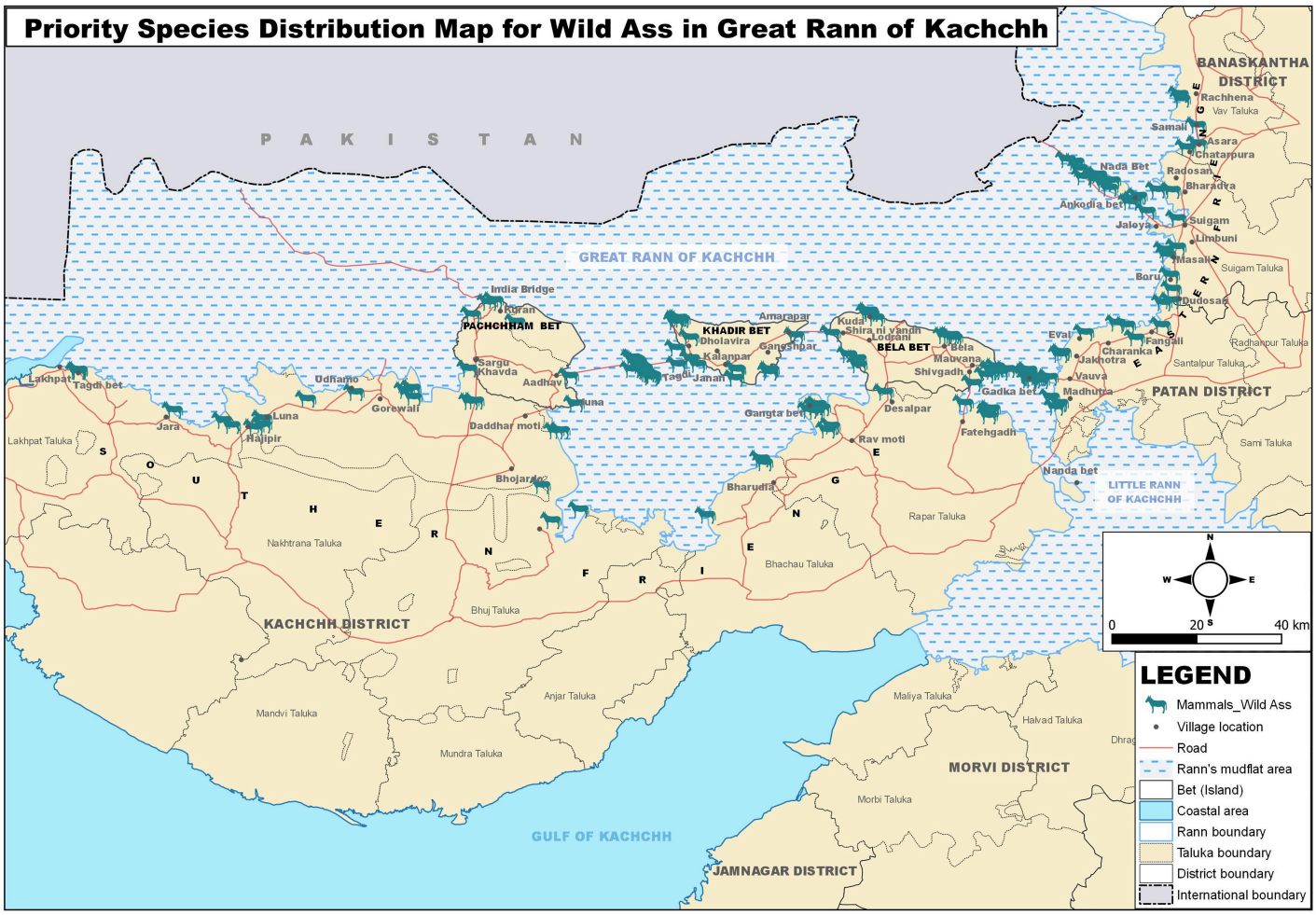


Figure 2

Distribution of Indian Wild Ass (*Equus hemionus khur*) over the Great Rann of Kachchh, Gujarat, India