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Land Use Land Cover Assessment of a Protected Area Complex in Western Terai Arc Landscape of India

Kalesar National Park and Wildlife Sanctuary (KNPWLS) situated in the state of Haryana, is an important protected area in the Terai Arc Landscape (TAL), providing connectivity between Simbalbara National Park and the Rajaji National Park. Authors examined the land use land cover (LULC) of KNPWLS using supervised classification and object-based classification methods, utilizing Sentinel-2B satellite imagery with a 10 m spatial resolution. The resulting LULC classes from both methods resulted in ten classes, viz. Sal forest, mixed forest, plantation, grassland, dry riverbed, waterbodies, built-up, agriculture, agroforest and wasteland. The findings reveal higher percentage of mixed forest (50.62%), followed by Sal forest (30.78%). The accuracy assessment reveals overall accuracy by 83%, supported by 79.71% of Kappa coefficient. This study provides the first comprehensive LULC map of KNPWLS, offering valuable insights for conservation and management planning. The findings serve as a critical tool for informed decision-making, helping to guide future biodiversity conservation efforts and sustainable land use management within the smaller protected areas.

Key words: Kalesar National Park and Wildlife Sanctuary, Supervised classification; Object-based classification, Remote sensing, Shivalik region

The authors examined the land use land cover (LULC) of Kalesar National Park and Wildlife Sanctuary using supervised classification and object-based classification methods. The resulting LULC classes from both methods resulted in ten classes.

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Introduction

In human-modified landscape, patches of Protected Areas (PAs) are the natural ecosystem. These PAs are essential for ecosystem functioning and ensure human well-being through provision of ecosystem services (Stolton *et al*., 2015). They act as carbon sinks, mitigate climate change, improve the quality of surface water and maintain the groundwater recharge (Kreye *et al*., 2014). They also help in stabilizing local climates and reduce the risk of disaster (Murti and Buyck, 2014). Studies have shown that well-managed PAs support higher species richness and abundance (Kearney *et al*., 2020). Globally, rise of population and increasing anthropogenic pressures such as agriculture expansion, urbanization and infrastructure development (Cumming, 2016; Wolf *et al*., 2023), has led to habitat fragmentation and biodiversity loss (Newbold *et al*., 2016). To monitor and protect PAs from unregulated exploitation and to assess their conservation effectiveness, Land Use Land Cover (LULC) mapping becomes an essential component of PA management.

Terai Arc Landscape (TAL) a transboundary area, which extends from south-central Nepal to the north-west India (Wikramanayake *et al*., 2010; Tiwari *et al*., 2024), includes 15 PAs. It is valued as a contiguous habitat for large mammals such as tiger (*Panthera tigris*), elephant (*Elephas maximus*) and one-horned rhinos (*Rhinoceros unicornis*) (Johnsingh *et al*., 2004; Chanchani *et al*., 2014). Tiger reserves (TRs) within TAL have been extensively studied for both species and spatial assessments (Mathur and Midha, 2008; Rawat and Parihar, 2024; Ghosh and Saha, 2025). Consequently, small PAs within the TRs have been geospatially assessed. However, smaller PAs outside TRs such as Kalesar National Park (KNP), Kalesar Wildlife Sanctuary (KWLS) and

Simbalbara National Park, have not been adequately studied. Small PAs are crucial as they act as wildlife corridors for the movement of large mammals across the larger landscape. Recent spotting of tiger in the Kalesar National Park (KNP) in 2023 after a gap of 110 years indicates that it still has the potential to be a tiger habitat and has a robust connectivity with Rajaji Tiger Reserve (Qureshi *et al.*, 2023). Despite its conservation significance, the LULC of KNPWLS has not been previously mapped (Sharma *et al.*, 2013; Habib *et al.*, 2015; Rai *et al.*, 2017; Sehgal *et al.*, 2022).

With the advancements in remote sensing and geospatial analysis, high-resolution satellite images provide an opportunity to fill this knowledge gap by facilitating accurate mapping and monitoring of LU changes (Kale *et al.*, 2016; Thakur *et al.*, 2020). Among the various satellite-based tools, Sentinel-2 data is preferred for LULC monitoring and climate change studies due to its improved spatial and spectral capabilities, providing accurate classification of diverse land cover types (Phiri *et al.*, 2020). This study provides a spatial baseline information for biodiversity monitoring, habitat assessment and effective conservation initiatives in the area.

Material and Methods

Study area

The study area is located between 30°20' to 30°38' N and 77°26' to 77°36' E in the Yamuna Nagar district of Haryana, India (Fig. 1). KWLS with an area of 54.36 km^2 was notified on 13th December 1996, and the KNP spread over an area of 46.82 km^2 was notified on 8th December 2003. This landscape of the Kalesar National Park and Wildlife Sanctuary together known as KNPWLS, falls under two biogeographic zones, namely Himalaya (2B) and Gangetic plain (7A) (Rodgers and Panwar, 1988). The KNPWLS is mainly dominated by Sal (*Shorea robusta*) and mixed forests with understorey of *Mallotus philippinensis, Murraya koenigii, Terminalia bellerica*, *Cassia fistula, Butea monosperma, Senegalia catechu, Nycthanthes arbor-tristics,* and riverine species such as *Dalbergisa sissoo* and *Senegalia catechu*. KNPWLS supports mammals like common leopard (*Panthera pardus*), Asiatic wildcat (*Felis silvestris*), Asiatic elephant (*Elephas maximus*), chital (*Axis axis*), barking deer (*Muntiacus muntjak*). KNPWLS is an Important Bird Area (IBA) (Rahmani *et al.*, 2016), with record of 161 species (Kalsi, 1998).

Data and Methods

For reliable LULC classification of KNPWLS, pre-processing was done on Sentinel-2B images (2019) using ERDAS Imagine software version 2023 and ArcGIS desktop software version 10.8.2. Atmospheric correction involved applying Dark Object Subtraction (DOS) and haze reduction tools in ERDAS to reduce atmospheric distortions like haze and water vapour. Geometric correction was conducted in ArcGIS with reference to Ground Control Points (GCPs) on topographic maps and field-measured GPS data with a Root Mean Square Error (RMSE) of less than 0.5 pixels

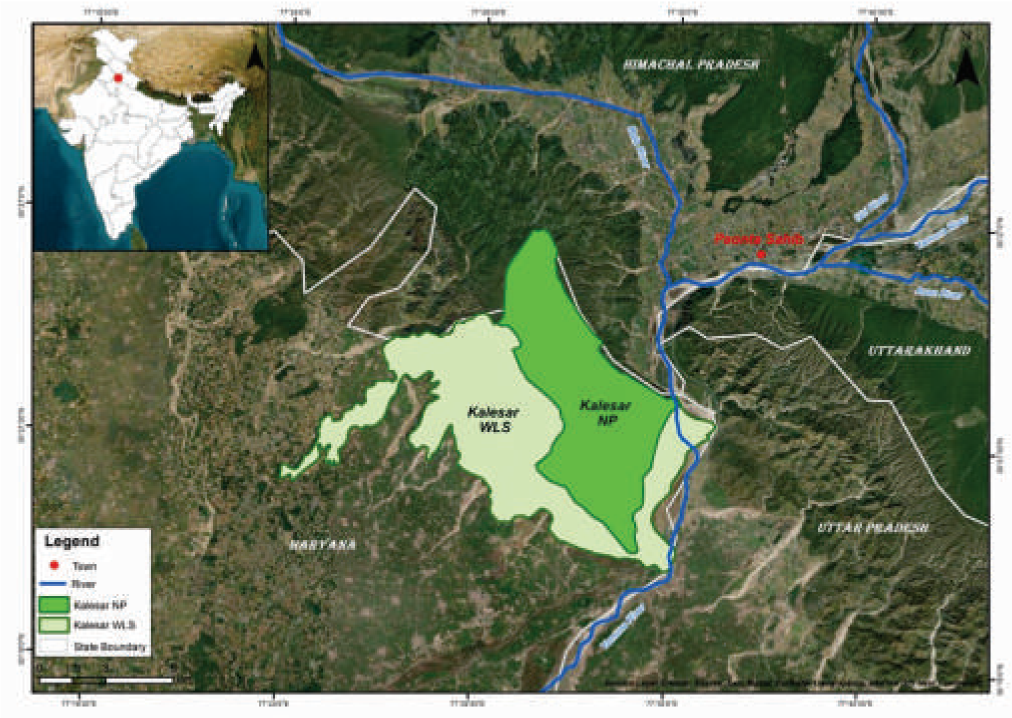

Fig. 1: Map of Kalesar National Park and Wildlife Sanctuary in the state of Haryana, India

to properly geo-align with UTM Zone 43N (WGS 84). Manually using digitization and visual examination, and assisted by false-colour composite, cloud masking was conducted to detect and remove cloud-impacted pixels. Quality assurance included visual cross-checks, with Survey of India toposheets at 1:50,000 scale (53F/6, 53F/7 & 53F/11) and field verification to ensure the quality of the pre-processed imagery, creating a solid foundation for classification.

Supervised and object-based approaches are common in use, but their combined use in this research introduces novelty in the form of a hybrid method. This study is the first to generate a high-resolution (10 m) LULC map of KNPWLS based on Sentinel-2B imagery. It integrates Maximum Likelihood Classification (MLC) in ERDAS Imagine with object-based classification in ArcGIS, applying both spectral and contextual information. In supervised classification approach, MLC was applied to categorize the pixels of the satellite imagery based on training data that was manually selected from known LULC classes. This statistical method computes the probability of each pixel belonging to a particular class by assuming a normal distribution of pixel values. This process generated spectral signatures for each LULC class. With above, an object-based classification was performed, which groups neighbouring pixels with similar spectral properties into objects or segments. These segments were then classified into different LULC classes based on additional spatial, spectral and contextual information. The resulting LULC classes from both methods include agriculture, agroforest, built-up, dry riverbed, grassland, mixed forest, plantation, sal forest, waterbodies and wasteland.

The overall accuracy and kappa coefficient were calculated, where classified images were validated with the ground truth points. We measured user's accuracy (Eq. 1), producer's accuracy (Eq. 2), overall accuracy (Eq. 3) and kappa coefficient (Eq. 4). Kappa coefficient was calculated to depict the agreement between classified and reference data. Based on accuracy metrics, we compared the performance of supervised and object-based classification and refined the classification errors wherever required (Mani *et al*., 2025). Table 1 shows Kappa coefficient rating criteria (Rwanga and Ndambuki, 2017). By analysing LULC patterns, we can identify the areas where sustainable management strategies are required, ensuring long-term biodiversity conservation in the region.

Results

KNPWLS spread over 101.18 km^2 is mainly dominated by forests. Based on the image interpretation and ground truth data points, this study identified 10 LULC classes (Fig. 2, Table 2). Within KNP, eight LULC classes were identified whereas in KWLS all the ten classes were present. More than 80% of the KNPWLS is under forest with highest area under mixed forest (50.62%), followed by Sal forest (30.78%) and small patches of plantation (0.23%). Sal forest covers larger area in KNP (57.33%) as compared to KWLS, whereas mixed forest covers larger area in KWLS (60.78%).

The dry riverbed covers 3.73% of the study area, which includes seasonal river and streams. Dry riverbed covers larger area in KWLS (5.19%) than KNP (2.03%). The human-modified areas include agricultural land (4.29%), agroforest (0.92%) and built-up (0.37%). Agriculture (7.47%) and agroforest (1.38%) is more prevalent in KWLS as compared to KNP (Table 2). Built-up land area in KWLS (0.61%) is comparatively larger than in KNP (0.06%), due to human-settlements in the east and southeast of the KWLS. Waterbodies occupy

User's Accuracy	=	*Number of Correctly Classified Pixels in each Category / Total Number of Reference Pixels in that Category (The Row Total)*	*(Eq.1)*
Producer's Accuracy	=	*Number of Correctly Classified Pixels in each Category / Total Number of Reference Pixels in that Category (The Column Total)*	*(Eq.2)*
Overall Accuracy (OA)	=	*Total Number of Correctly Classified Pixels (Diagonal) / Total Number of Reference Pixels* x 100	*(Eq.3)*
Kappa Coefficient (k) *TS (); TCS ()	=	$\frac{(TS \times TCS)^{*} - \sum(\text{Column Total} \times \text{Row Total})}{(TS)^2 - \sum(\text{Column Total} \times \text{Row Total})} \times 100$	*(Eq.4)*

Table 1: Rating criteria of Kappa Coefficient

Kappa Coefficient	Strength of agreement
<0	Poor
0.00 – 20.00	Slight
21.00 – 40.00	Fair
41.00 – 60.00	Moderate
61.00 – 80.00	Substantial
81.00 – 100	Almost perfect

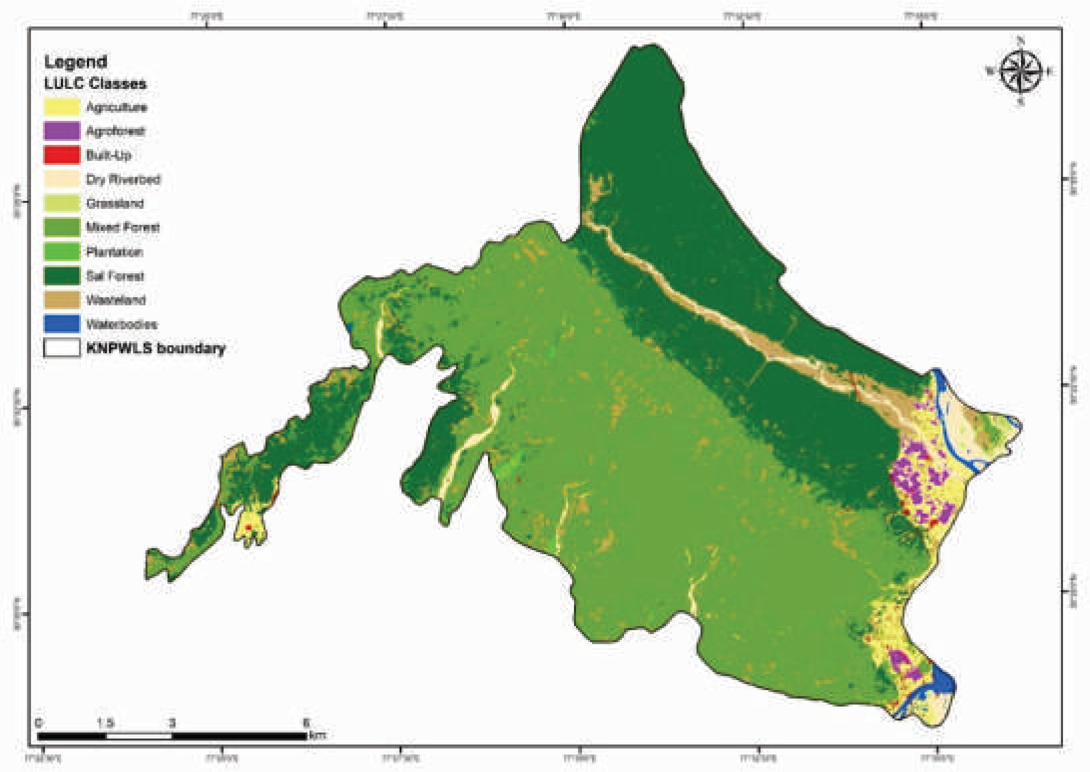

Fig. 2 : Land use land cover of the Kalesar National Park and Wildlife Sanctuary in Haryana, India

Table 2: Area under different LULC classes within the KNPWLS

LULC Classes	KNP		KWLS		KNPWLS	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Agriculture	0.46	0.98	4.06	7.47	4.34	4.29
Agroforest	0.16	0.34	0.75	1.38	0.93	0.92
Built-up	0.03	0.06	0.33	0.61	0.37	0.37
Dry Riverbed	0.95	2.03	2.82	5.19	3.77	3.73
Grassland			0.28	0.52	0.33	0.33
Mixed Forest	14.77	31.55	33.04	60.78	51.23	50.62
Plantation			0.22	0.4	0.23	0.23
Sal Forest	26.84	57.33	7.87	14.47	31.15	30.78
Wasteland	3.52	7.52	4.39	8.08	8.11	8.02
Waterbodies	0.09	0.19	0.6	1.1	0.72	0.71
Total	**46.82**	**100**	**54.36**	**100**	**101.18**	**100**

0.71% of the study area. As compared to KNP, KWLS has 1.1% area under waterbodies because of the presence of Yamuna River in the eastern part. Waterbodies like reservoir constructed inside the national park covers 0.19% area. The overall accuracy assessment of the study area was high with 83% and kappa coefficient was 79.71% (Table 3), which means substantial agreement between the classified LULC types and reference data (Table 1).

Discussion

TAL is a crucial conservation area, which provides habitat connectivity for larger mammals like tigers, elephants, rhinos and other species. Forest patches in the landscape are connected by narrow wildlife corridors (Johnsing *et al*., 2004; Qureshi *et al*., 2023). Over recent decades, rapid LULC changes happened in the landscape due to increased human-settlements, linear developments such as road and rail networks, urbanization and agricultural expansion, which led to the habitat fragmentation of forest and grasslands. Although the larger PAs in the landscape are important, but smaller PAs like KNPWLS act as stepping stones between larger PAs. Understanding the LULC pattern of smaller PAs plays crucial role in conservation and management by improving habitat connectivity and

Table 3: LULC classes and their accuracy assessment

	Reference data											
LULC Class	Agriculture	Agroforest	Built-up	Dry Riverbed	Grassland	Mixed Forest	Plantation	Sal Forest	Wasteland	Waterbodies	Total (User)	User's Accuracy
Classified data												
Agriculture	**15**	1	0	1	0	0	1	0	0	0	18	0.83
Agroforest	2	**7**	0	0	0	1	0	0	0	0	10	0.70
Built-Up	0	0	**5**	1	0	0	0	0	0	0	6	0.83
Dry Riverbed	0	0	2	**10**	0	0	0	0	1	0	13	0.77
Grassland	0	0	0	0	**3**	0	0	0	1	0	4	0.75
Mixed Forest	0	1	0	0	0	**30**	1	5	0	0	37	0.81
Plantation	0	0	0	0	0	2	**3**	0	0	0	5	0.60
Sal Forest	0	0	0	0	0	3	0	**24**	0	0	27	0.89
Wasteland	0	0	0	1	1	0	0	0	**17**	0	19	0.89
Waterbodies	0	0	0	0	0	0	0	0	0	**6**	6	1.00
Total (Producer)	17	9	7	13	4	36	5	29	19	6	**145**	
Producer's Accuracy	0.88	0.78	0.71	0.77	0.75	0.83	0.60	0.83	0.89	1.00		
Overall Accuracy (OA) = 83 %												
Kappa Coefficient (κ) = 79.71 %												

supporting wildlife (Qureshi *et al*., 2023). This study provides the first baseline LULC pattern of the KNPWLS.

The study highlights that human-modified land use, such as agriculture and allied activities and built-up areas, is more concentrated along the periphery. This indicates human encroachment or utilization of land near the edges, likely due to proximity to transportation networks and resource availability (Chandola *et al*., 2008). Increased anthropogenic activities could lead to fragmentation, loss of vegetation cover and encroachment in KNPWLS, if not managed effectively.

Accuracy assessment is a significant step for evaluating the reliability of supervised classification technique (Rwanga and Ndambuki, 2017). In our study the overall accuracy was 83% and Kappa coefficient was 79.71%, which indicates substantial agreement between classified and reference data (Congalton and Green, 2019; Ahmad *et al*., 2023). Although misclassification was common in mixed forest, harbouring interspersed grasses on the forest floor. This could be due to spectral mixing of vegetation layers (Geerling *et al*., 2007).

Conclusion

The study suggests that KNPWLS still has natural forests, but the anthropogenic activities particularly along the fringes make the PA vulnerable to fragmentation and changes. The KNPWLS being an important stepping stone, improves habitat connectivity, crucial for maintaining ecological integrity and biodiversity in the broader landscape. Factors such as increasing human population density, agricultural expansion negatively influence the natural LULC of the PAs. To safeguard biodiversity in smaller PAs, landscape level conservation is required. At landscape level, TAL conservation approach has strengthened the landscape connectivity by integrating small forest patches through wildlife corridors. This landscape approach to conservation will ensure the long-term viability of smaller PAs like KNPWLS (Harihar *et al*., 2009; Wikramanayake *et al*., 2010; Li *et al*., 2025).

भारत के पश्चिमी तराई आर्क परिदृश्य में एक संरक्षित क्षेत्र के भू-उपयोग और भू-आवरण का विश्लेषण

प्रीति कुमारी, आशीष मणि, साक्षी राणा, रुचि बडोला और सैयद ऐनुल हुसैन

सारांश

हरियाणा राज्य में स्थित कालेसर राष्ट्रीय उद्यान एवं वन्यजीव अभयारण्य (केएनपीडब्ल्यूएलएस), तराई आर्क परिदृश्य (टीएएल) में एक महत्त्वपूर्ण संरक्षित क्षेत्र है, जो सिंबलबाड़ा राष्ट्रीय उद्यान और राजाजी राष्ट्रीय उद्यान के बीच पारिस्थितिकीय संपर्क प्रदान करता है। हमने सेंटीनेल–2बी उपग्रह चित्रों (10 मीटर स्थानिक विभेदन) का उपयोग करते हुए केएनपीडब्ल्यूएलएस के भूमि उपयोग एवं भू–आवरण (एलयूएलसी) का मूल्यांकन पर्यवेक्षित वर्गीकरण और वस्तु–आधारित वर्गीकरण विधियों के माध्यम से किया। दोनों विधियों से प्राप्त एलयूएलसी वर्गों की कुल संख्या दस रही, जो निम्नलिखित हैं: साल वन, मिश्रित वन, रोपण क्षेत्र, घासभूमि, सूखी नदी की तलहटी, जलाशय, निर्मित क्षेत्र, कृषि भूमि, कृषि वानिकी, तथा परित्यक्त भूमि। अध्ययन से पता चला कि सबसे अधिक क्षेत्र मिश्रित वन (50.62%) से आच्छादित है, जिसके बाद साल वन (30.78%) का स्थान है। सटीकता मूल्यांकन के अनुसार अध्ययन की कुल सटीकता 83% पाई गई, जिसे 79.71% कप्पा गुणांक द्वारा समर्थन प्राप्त है। यह अध्ययन केएनपीडब्ल्यूएलएस का पहला व्यापक एलयूएलसी मानचित्र प्रदान करता है, जो संरक्षण एवं प्रबंधन योजना के लिए महत्त्वपूर्ण जानकारी उपलब्ध कराता है। यह निष्कर्ष साक्ष्य–आधारित निर्णय लेने के लिए एक महत्त्वपूर्ण उपकरण के रूप में कार्य करता है, जो भविष्य में जैव विविधता संरक्षण और सतत भूमि प्रबंधन के प्रयासों को दिशा देने में सहायक होगा, विशेष रूप से छोटे संरक्षित क्षेत्रों के संदर्भ में।

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