Human-Wildlife Conflict Mobility and Landscape-Level Safeguarding Forests through UAV Applications

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Abstract: Conflict between humans and wildlife that results in the loss of life, property, or resources is referred to as human-wildlife conflict. The natural habitats of the animal kingdom will inevitably be invaded by humans due to the growing human population. Because of this, many countries have integrated human-wildlife conflict mitigation into their national environmental teams. The goal of this endeavor is to better protect human lives and save animals. When interactions between people and wildlife result in detrimental outcomes like the loss of property, livelihoods, or even life, this is known as HWC. Human proximity to wildlife's natural habitats is one of the elements causing conflict between humans and wildlife. The importance of geospatial technology, such as remote sensing (RS) and geographic information systems (GIS), as effective tools for mapping, tracking, and controlling regions affected by conflicts between humans and wildlife is examined in this paper. RS entails gathering data without making direct physical contact. RS is adamant about recognizing important elements that lead to conflicts in the context of HWC, such as resource availability in forest areas and habitat changes. The unification and analysis of spatial data are made possible by GIS. For example, herbivores graze crops, while carnivores graze animals, forcing farmers who depend on both to take drastic steps to save wildlife extinction. Conflicts between humans and wildlife can manifest as crop damage, livestock loss, disease transfer, human injury, and fatalities in the vicinity of protected areas.

1. Introduction:

The elements leading to human-animal conflict are humans coming into proximity to the natural habitats of wildlife. For instance, crops are increased by herbivores and cattle by carnivores, causing the farmers who depend on both to take considerable steps to prevent the loss of wildlife. Human–Wildlife Conflict (HWC) is an increasing worry for local communities living in the vicinity of protected areas. These conflicts can appear in the form of crop damage, livestock loss, disease transmission, human injury, and death around protected areas. The encounters between them have become more frequent, and not all interactions between the two groups are positive (Gross et al., 2021). Wildlife can endanger the safety, livelihood, and well being of human, resulting in retaliation against the species responsible and dispute over how to address the situation (Nyhus, 2016). Human-wildlife conflict (HWC) can take various forms, making it challenging to precisely define what constitutes such conflict. HWC presents a major and growing danger to the existence of numerous species, and conservation biologists are paying more attention to this issue (Dickman, 2010; Zimmermann et al., 2020). The issue is a worldwide concern, impacting both advanced and emerging countries (König et al., 2020). Present wildlife populations and farming methods make large mammalian predators and commercial agriculture the primary examples of human-wildlife conflict in most developed countries such as the USA, Norway, Italy, Canada, and Australia. Examples consist of the brown bear, lynx, grey wolf, and wolverine, which primarily hunt sheep and cattle bred for commercial use (Seoraj-Pillai and Pillay, 2017). The predation of humans and livestock by carnivores like tigers and snow leopards in India, leopards in Zimbabwe, Tanzania, and Pakistan, as well as lions in Africa, is a significant cause of conflict in developing nations (Carter et al., 2014; Kesch et al., 2015).

1.1 Causes of Human-Elephant Conflict in Kaziranga National Park

Habitat Fragmentation: Deforestation and infrastructure development disrupt elephant corridors, forcing elephants to traverse human settlements (Dickman, 2010; Zimmermann et al., 2020).

Encroachment: Expansion of agricultural lands and settlements into forested areas reduces habitat availability and increases interaction zones. Built-up areas, such as Kanchanjuri East, Baguri West, and Panbari West, which are critical wildlife corridors, restrict elephant movement due to growing urbanization.

Agricultural Practices: Cultivation of crops like paddy and sugarcane, which are attractive to elephants, intensifies crop-raiding incidents.
activities within buffer zones and protected areas disturb wildlife habitats.

Seasonal Migration: Elephants' seasonal movement in search of food and water often leads them into human-dominated areas.

Lack of Awareness and Mitigation Measures: Insufficient knowledge about sustainable coexistence and limited implementation of conflict mitigation strategies exacerbate the problem.

The main source of data for this study was incidents of human-elephant conflict that took place in the forest ranges of Keonjhar Forest Division, East India (Figure 1). The research region, which is roughly 6,038 km2, is situated between latitudes 21°1′ N–22° 10′ N and 85°11′ E–86°22′ E. The study region is the mining center of the province of Odisha, where forest areas are typically home to minerals including manganese (Mn), iron (Fe), and chromite (Cr). The dense forest that covers over 30% of the land is primarily made up of Northern tropical deciduous trees such the Sal tree (Shorea robusta), Asan (Terminalia elliptica), Jamu (Syzygium cumini), Mahua (Madhuca longifolia), Mango (Mangifera indica), and Kendu (Diospyros melanoxylon). Drone footage will be used to monitor certain creatures, such as elephants, tigers, rhinoceroses, etc.

2. Literature survey

The existence of many species is seriously threatened by disputes over wildlife, sometimes known as human-wildlife conflicts (HWCs) (Dickman, Marchini, & Manfredo, 2013; Woodroffe, Thirgood, & Rabinowitz, 2005; Inskip & Zimmermann 2009). Human-wildlife conflict occurs when wildlife needs and behaviors negatively impact human goals or, on the other hand, when human activities negatively impact wildlife needs (Sillero et al., 2001; Madden, 2004; Mekonen, 2020). Conflict between humans and animals arises when either humans negatively impact the requirements of wildlife or the needs of wildlife negatively effect humans. Local people that live close to protected areas are becoming increasingly concerned about human-wildlife conflict (HWC).In the vicinity of protected areas, these conflicts may manifest as crop damage, animal loss, disease spread, human harm, and fatalities. HWCs are not exclusive to rural areas or impoverished nations; they can be found everywhere. Climate change, habitat conversion, and species recovery and reintroduction are all contributing factors to the growing interaction between humans and wildlife. According to Fehlmann, O'Riain, Kerr-Smith, and King (2017), the phenomena also occurs in urban settings where people and wildlife coexist. Large predators are compelled to cohabit with humans in multiple-use landscapes by sharing resources and space due to an increase in human-induced modifications to natural habitats Lercari (2021).

In a fragmented landscape, GPS data can be utilized to determine behavioral states and record spatial patterns of resource choices in response to season and periods of human activity. Human health, safety, and welfare, as well as ecosystem health and biodiversity, are all negatively impacted by human-wildlife conflict. People may experience direct or indirect repercussions. Animals may crash with cars, trains, airplanes, boats, ships, or other vehicles; they may attack humans directly by biting, clawing, cutting, or using other methods; or they may infect humans with parasites or zoonotic diseases (Conover, 2002; Nyhus, 2016).

Large habitats are necessary for wild animals to survive, and these habitats sometimes overlap with agricultural land and human populations close to Protected Areas. The primary causes or initiators of HWC include, but are not limited to, human population growth, land conversion, land-use patterns, encroachment on wildlife habitat, and developmental operations in and around Protected Areas. Human-wildlife conflict is more likely to occur in protected areas and their environs, and residents of these regions suffer from crop loss as a result of crop raiding, livestock predation, human injury, and occasionally even death. The fear of wildlife endangering crops, livestock, and human lives encourages rural residents to kill wildlife and reduce the quantity and quality of habitat on both public and private holdings. Residents of Protected Areas are even more susceptible to wild animal species that cause problems (Nyhus et al., 2009).

2.1. Objectives

Identify and map critical wildlife corridors and conflict-prone areas in and around Kaziranga Nationalpark. Analyze land use patterns and built-up areas that intersect with elephant movement pathways. Develop strategies to mitigate human-elephant conflicts, ensuring safe mobility for elephants and reduced risks to local communities. Promote sustainable land-use practices in buffer zones to balance ecological conservation and human development. Strengthen community engagement and policy frameworks for long-term conservation and conflict management.

2.2. **Problem Statement**

Human-elephant conflicts in and around Kaziranga National Park are escalating due to habitat fragmentation, encroachment on wildlife corridors, and increasing built-up areas.

These conflicts lead to significant challenges, including crop damage, property destruction, and risks to both human and elephant lives. The lack of effective land-use planning and insufficient mitigation strategies exacerbate the vulnerability of critical areas such as Kanchanjuri East, Baguri West, and Panbari West, where human activities overlap with essential elephant movement pathways. This underscores the urgent need for comprehensive solutions to ensure the coexistence of humans and wildlife while safeguarding the ecological integrity of the region.

2.3. **Human Wildlife in Kaziranga National Park**

Kaziranga National Park is situated beside the Brahmaputra River in central Assam. About 50,000 farms surround the park, making it a heavily inhabited area with 500 people per square kilometer. Agriculture, cattle breeding, and fishing are the main sources of income for the locals, and some of these pursuits are carried out on transient islands in the Brahmaputra River's bed. During the monsoon season, these islands—known as saporis in Assam—become inundated.

(a) (b)

Figure 1(a), (b) shows that the movement of elephants roaming around the KNP

The increasing number of well-protected wild animals in the National Park has a drawback in that they sometimes stray outside the park's boundaries, frightening people, hurting farmers, and destroying cattle and crops. In fact, tigers terrorize populations and murder cattle, while herds of elephants—which can number over a hundred—and rhinoceroses frequently destroy homes, crops, and occasionally even kill humans. The number of people slain, the homes and areas of crops damaged, and the hundreds of rhinos and elephants killed can all be counted. From year to year, this terrible circumstance has gotten worse. In actuality, the Par and its environs resemble a battleground with several casualties on both sides (cf. Smadja 2013). Elephants, rhinoceroses, buffaloes, tigers, leopards, jackals, and many types of monkeys are among the herds of every species found in this work. All of them seriously damage crops, but elephants in particular frequently destroy granaries throughout the day in order to obtain the salt and grain (Saikia 2005:254). Elephants' natural habitat is quickly disappearing as a result of increased land clearance for industrial and agricultural purposes. Due to human encroachment, elephants were forced to forage in exposed locations, increasing the risk of upsetting the local community.

(a) (b) (c) (d)

Figure 2: (a),(b),(c),(d) A few of the additional creatures under human observation.

3. Methodology

Proxies for Input Predictor Variables Derived from Satellite Data: For the ML models, a total of 37 predictor variables from the LISS IV, SAR, PALSAR, and SRTM data were produced (Table 1). Bi-linear interpolation was used to resample the predictor variables to a spatial resolution of five meters. This change was implemented in order to lower the total volume of data and standardize the data resolution. The height map of the canopy was also produced at a resolution of five meters. Remote sensing with Drone monitoring helps to improves the surveilliance of the KNP. Next process identify objects close to the elephant pathways and notify visitors of a safer area.

CAUSES of HWC: Urbanization, infrastructure development, agricultural expansion, and climate change are the main causes of conflicts between humans and wildlife.

Figure 3: This image suggests the work's study area.

- **Study area: Kaziranga National Park, Assam, India** is located at *India* country in the *National Parks* place category with the coordinates of 26° 34' 33.1068" N and 93° 10' 1.3656" E. The Kaziranga Proposed Reserve Forest was created with an area of 232 square km on 1st June 1905 and with the enactment of Assam National Park Act of 1968 it was declared as the National Park. It is a protected area that is rich in natural beauty and diversity of flora and fauna.

3.1. Current Research on Human-Animal Conflict

- 222 elephants were killed by electrocution across the country between 2018-19 and 2020-21. Out of which 45 deaths caused by trains, 29 by poachers and 11 by poisoning.
- Among the number of elephants died because of electrocution, Odisha accounted for 41, followed by Tamil Nadu and Assam for 34 and 33 respectively.
- Odisha also tops the list of highest number of elephant deaths caused by trains which is (12 out of 45), followed by West Bengal (11) and Assam (9).

- Elephants death by Poaching were highest in Meghalaya (12 out of 29) while poisoning deaths were highest in Assam.

Similarly, if we talk about human causalities of conflict with animals, 1,579 humans are killed by elephants in three years that is 585 in 2019-20, 461 in 2020-21, and **533 in 2021-22**.

Odisha accounted for the highest number of these deaths at 322, followed by Jharkhand at 291 (including 133 in 2021-22 alone), West Bengal at 240, Assam at 229, Chhattisgarh at 183, and Tamil Nadu at 152.

Table : 1 Conflict between Humans and Wildlife

S.No	Particulars	2019-20	2020-21	2021-22	2022-23	2023-24
1	Elephants Kill Humans	533	461	585	118	__
2	Elephants Killed by Trains	12	14	19	21	__
3	Elephant deaths caused by electrocution	65	76	81	23	11
4	Elephant deaths due to poaching	14	9	6	2	1
5	Elephants die from poisoning	14	9	06	2	1

3.2 Land Use and Land Cover Change Analysis Applications

One of the most important uses of RS and GIS integration is land use and land cover (LULC) change analysis. The physical features of the Earth's surface, such as forests, marshes, water bodies, and urban areas, are referred to as land cover, but the human use of these lands, such as agriculture, settlement, and industry, is referred to as land use. Up-to-date, high-resolution images from remote sensing is essential for identifying and measuring changes in LULC over time. Researchers can map various land cover types and track their transitions, such as urbanization into agricultural land or deforestation in tropical regions, by using classification algorithms on satellite data. By including spatial data on species distribution, protected areas, and changes in land use, GIS improves biodiversity monitoring. Conservationists can use GIS to design habitat restoration initiatives, evaluate the efficacy of current reserves, and identify priority locations for protection through spatial analysis. GIS techniques make it possible to model possible habitat ranges under various climate scenarios, which aids in forecasting changes in biodiversity brought on by climate change. By providing complicated ecological data in an understandable format, GIS's visualization capabilities can help to increase public awareness and direct policy decisions.

Table 2: Land use Land cover status of the Elephant Corridors and its Buffer areas

LAND USE/LAND COVER STATUS OF THE ELEPHANT CORRIDORS AND ITS BUFFER AREAS													
AREA IN HECTARES													
LAND USE CLASSES	AMGURI EAST	BAGURI WEST	CHIRANG	DEOSUR	HALDIBHARI EAST	HALDIBHARI WEST	HARMATI EAST	HARMATI WEST	HATIDANDI EAST	KANCHANJURI EAST	PANBARI EAST	PANBARI WEST	TOTAL AREA
AGRICULTURE LAND	1.665	40.694	0.500	6.281	20.736	6.646	18.416	13.223	4.559	36.620	9.669	31.319	190.329

BUILT-UP	*	**5.940**	**0.150**	**0.906**	**0.416**	**1.473**	**1.867**	**3.016**	**0.642**	**8.184**	**0.750**	**4.032**	**27.377**
FOREST	**18.814**	**0.669**	**44.960**	**11.255**	**5.735**	**9.007**	**10.689**	**10.553**	**27.798**	**3.167**	**9.062**	**4.253**	**155.962**
PLANTATION	**37.765**	**9.787**	**29.128**	**26.067**	**37.670**	**32.427**	**23.742**	**33.099**	**37.563**	**7.370**	**40.319**	**21.592**	**336.530**
SANDBAR	*	**0.010**	*	*	*	*	*	**0.480**	*	**22.748**	*	*	**23.239**
SCRUBLAND	**20.213**	**21.357**	**3.718**	**33.318**	**13.902**	**25.187**	**19.158**	**16.581**	**7.895**	*	**18.662**	**17.264**	**197.255**
WATERBODY	*	*	*	**0.630**	*	**3.717**	**4.586**	**1.505**	*	**0.367**	*	*	**10.805**

3.3. Support for Sustainable Development and Environmental Impact Assessment

When doing Environmental Impact Assessments (EIAs), a procedure used to assess the possible environmental effects of proposed projects or policies prior to implementation, the integration of RS and GIS has become essential. For the purpose of assessing the beginning stage of the environment, remote sensing provides baseline environmental data, such as vegetation cover, water resources, and current land use patterns.

4. Environmental Data Acquisition using Remote Sensing

Because remote sensing can cover a large area of the Earth's surface repeatedly with little human interaction, it has become a crucial technique for gathering environmental data. Land cover, vegetation indices, water bodies, and atmospheric conditions can all be thoroughly observed thanks to the data that satellites and airborne sensors collect in a variety of spectral bands, such as visible, infrared, and microwave. This skill makes it easier to identify environmental changes over time, including urbanization, glacier retreat, deforestation, and desertification [8]. This helps emergency planners allocate resources effectively and prioritize response operations. In the long run, this integration facilitates the creation of resilience planning tools, risk maps, and vulnerability assessments—all of which are essential for disaster preparedness and climate change adaptation.

5. Results and Discussions

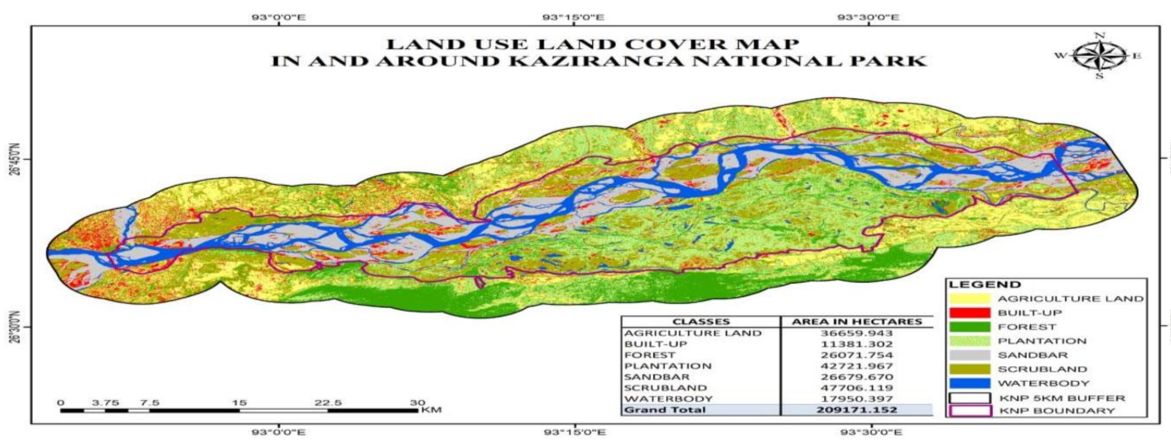

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Figure 4: The figure illustrates the integrated worklow of remote sensing, aerial surveys, and GIS in environmental monitoring around the KNP. It demonstrates how spatial data is collected, processed, and analyzed to support effective decision-making and sustainable resource management.

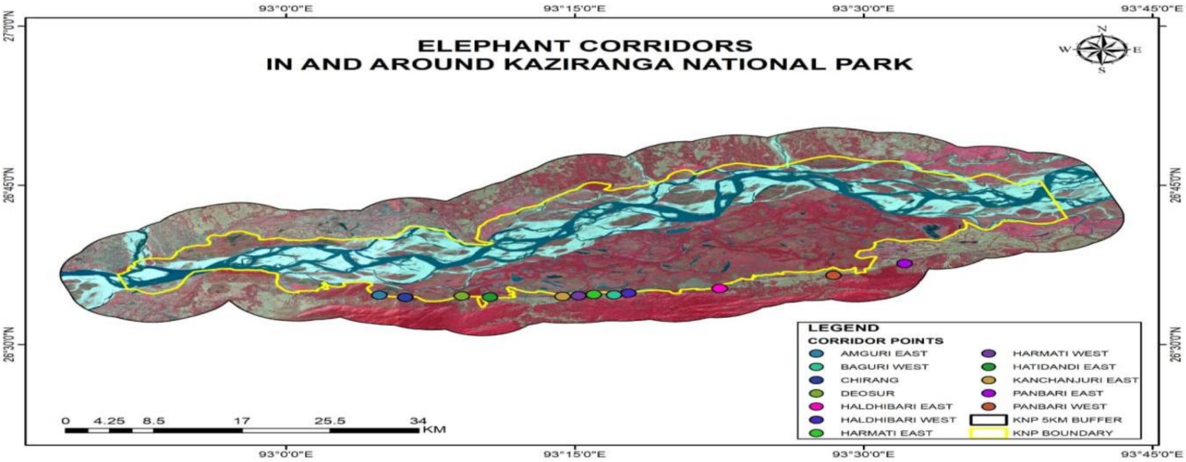
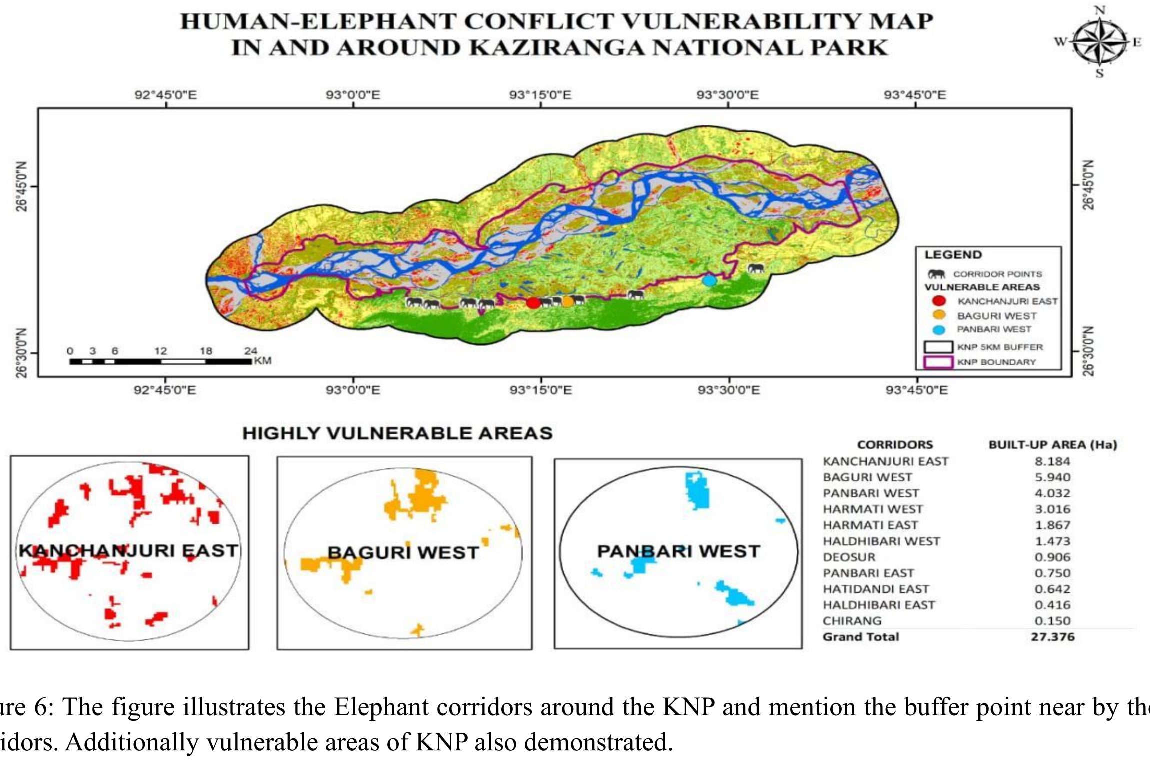


Figure 5: The figure illustrates the Elephant corridors around the KNP, and mention the buffer point near by the corridors.



CORRIDORS	BUILT-UP AREA (Ha)
KANCHANJURI EAST	8.184
BAGURI WEST	5.940
PANBARI WEST	4.032
HARMATI WEST	3.016
HARMATI EAST	1.867
HALDHIBARI WEST	1.473
DEOSUR	0.906
PANBARI EAST	0.750
HATIDANDI EAST	0.642
HALDHIBARI EAST	0.416
CHIRANG	0.150
Grand Total	**27.376**

Figure 6: The figure illustrates the Elephant corridors around the KNP and mention the buffer point near by the corridors. Additionally vulnerable areas of KNP also demonstrated.

The image is a land use and land cover map of Kaziranga National Park and its surrounding areas. The map displays a variety of land types, differentiated by color, and is overlaid on a geographical coordinate grid. The title "LAND USE LAND COVER MAP IN AND AROUND KAZIRANGA NATIONAL PARK" is prominently displayed at the top, centered.

A vast, winding river system that flows horizontally over the globe and is portrayed in vivid blue is the main geographical feature. The river is distinguished by its many tributaries, channels, and sandbars, all of which are depicted in different tones of grey and blue. The river is surrounded by a variety of land cover types. Forests and scrubland are represented by green tones, which range from light to dark. Agricultural land is indicated by

yellowish-brown regions. Built-up areas are indicated by red spots, which may indicate infrastructure or human populations. Sandbars are shown by light grey patches, the KNP 5km buffer zone by a clear dark red line, and the KNP boundary by a purple line. The map has a somewhat organic shape because it is surrounded by an uneven, scalloped border. The scale, which ranges from 0 to 30 km, is shown at the bottom of the map with matching numerical markers. The top and bottom edges (longitude) and left and right edges (latitude) show the geographical coordinates in degrees and minutes. Each land cover class—Agriculture Land (yellow), Built-Up (red), Forest (dark green), Plantation (light green), Sandbar (light grey), Scrubland (olive green), Waterbody (blue), KNP 5KM buffer (dark red line), and KNP boundary (purple line)—has a legend in the lower right corner that explains the color coding.
A table labeled "CLASSES" and "AREA" is located beneath the map, to the left of the legend.

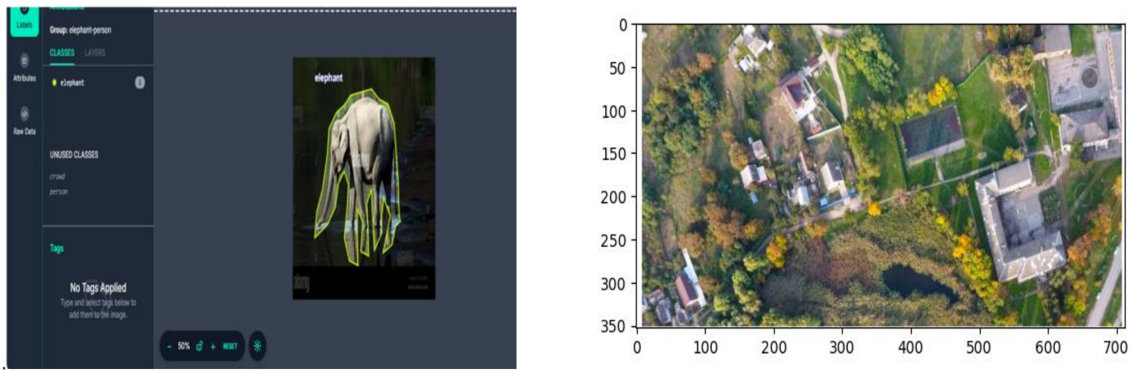
Below the map, to the left of the legend, is a table titled "CLASSES" and "AREA IN HECTARES". This table lists the different land cover types and their corresponding areas in hectares, providing quantitative data for each category. The Grand Total area is also provided.

The overall composition is informative and analytical, designed to present a clear visual representation of the land use patterns within and around the national park. The color palette, while diverse, is effectively used to distinguish between different land categories. The map's orientation is such that the river flows roughly from west to east. A compass rose is subtly placed in the upper right corner, indicating North.

This map highlights human-elephant conflict vulnerability in and around Kaziranga National Park, emphasizing critical areas where interactions between human activities and elephant movement are most pronounced. Three highly vulnerable regions—Kanchanjuri East, Baguri West, and Panbari West—are identified, each characterized by significant overlap between built-up areas and wildlife corridors.

4.1. Key insights include

Critical Wildlife Corridors: The map delineates essential routes facilitating elephant movement, overlapping with built-up zones, particularly in Kanchanjuri East (8.184 ha), Baguri West (5.940 ha), and Panbari West (4.032 ha).
Buffer Zones: A 5 km buffer zone around Kaziranga National Park underscores areas requiring strategic management to mitigate conflicts and protect ecological integrity.
Land Use Patterns: Built-up areas within corridor regions, totaling 27.376 ha, signify potential hotspots of human-elephant interactions, necessitating targeted interventions.



(a) (b)

Figure 7(a),(b): Identify objects close to the elephant pathways and notify visitors of a safer area.

4.2. Description of workflow

The image displays a user interface for image annotation. The "Labels" section is expanded, showing a "Group: elephant-person." Below this, there are two tabs: "CLASSES" and "LAYERS." The "CLASSES" tab is selected, and it lists "elephant" with a small yellow dot next to it, indicating it's an active label. There's also an information icon next to "elephant." Below the active class, under "UNUSED CLASSES," "crowd" and "person" are listed. Further down, there's a "Tags" section that currently says "No Tags Applied." The main content of the image, displayed on the right, is an image of an elephant. The elephant is a large, grey animal with its trunk hanging down. It appears to be standing in or near water, with reflections visible. The background is a blurred, dark green and brown landscape, suggesting a natural environment like a forest or savanna. A bright yellow outline, also known as a bounding box or segmentation mask, is drawn around the entire body of the elephant, precisely outlining its shape. The yellow outline on the elephant is a prominent feature, clearly delineating the object of interest for annotation.

4.3 Remote Sensing Image Classification Operates

Image Acquisition: Obtaining satellite imagery is usually the first step in remote sensing classification. This typically entails the use of many bands, such as red, green, blue, etc.

Preprocessing: The raw satellite data needs to be cleaned and adjusted before any classification can take place. This covers atmospheric, geometric, and radiometric corrections. These modifications guarantee that the image is consistent and usable for additional investigation.

Gathering Training Data: Labeled data is essential for supervised learning. This entails manually choosing regions of the image where the true kind of land cover—such as buildings, vegetation, or water—is known. These are gathered by field surveys or GIS tools and serve as ground truth.

Feature extraction: The values of each pixel in remote sensing data span several spectral bands. These values serve as characteristics. Utilize derived indices or raw pixel values along with other features like texture, descriptors, etc.

Classifier Selection: A classification model is then chosen. This could be more intricate deep learning techniques like CNNs or U-Net, or it could be a straightforward machine learning algorithm like Random Forest or SVM. The decision is based on the amount of data, the level of accuracy needed, and the computing power at hand. Traditional ML classifiers are frequently adequate for basic jobs.

Classification: The chosen model is applied to the remainder of the image after being trained on the labeled samples. A terrain cover class, such as forest, lake, or urban, is assigned to each pixel.

Post-processing: The final map may be dispersed or noisy following classification. Post-processing methods like majority filtering and smoothing are used to enhance the visual quality.

Accuracy Assessment: Lastly, the classification's quality is assessed. This involves figuring out the general accuracy, confusion matrix, etc. These indicators offer a clear picture of the model's effectiveness.

A collection of buildings in different sizes and styles may be seen in the composition. A number of smaller, residential-looking structures with dark roofs and white and beige walls may be found in the upper left quadrant. More intricate structures can be seen more into the image, closer to the center, including what appears to be a sizable, multi-story building with a light-colored front and a number of connected portions. A large amount of the frame is taken up by a substantial, lighter-colored building to the right that has a visible roof structure.

5.Conclusion

The increasing human-elephant conflict in and around Kaziranga National Park is a complex issue driven by habitat fragmentation, encroachment, and human activities in critical wildlife corridors. Areas like Kanchanjuri East, Baguri West, and Panbari West have emerged as conflict hotspots, highlighting the urgent need for targeted conservation efforts. Addressing these challenges requires a multi-faceted approach, including habitat restoration, sustainable land-use planning, and community-driven conflict mitigation strategies. By fostering coexistence through innovative solutions and robust policies, it is possible to safeguard both human livelihoods and elephant populations, ensuring the ecological balance of this biodiverse region. Through satellite imaging and airborne surveys, remote sensing offers unmatched access to large-scale, real-time environmental data, collecting vital characteristics like water quality, vegetation health, land cover, and climate indicators. It is feasible to find spatial patterns, identify changes over time, and forecast future environmental trends when this abundance of data is examined within a GIS framework. By improving the accuracy, effectiveness, and scope of monitoring operations, the RS-GIS integration enables proactive environmental management and resource planning, making it an essential tool for researchers, policymakers, and environmental managers tasked with addressing global environmental challenges.

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