**HUMAN-ANIMAL CONFLICT**

***A***

***Project Report***

*submitted in partial fulfillment of the*

*requirements for the award of the degree of*

**BACHELOR OF TECHNOLOGY**

**in**

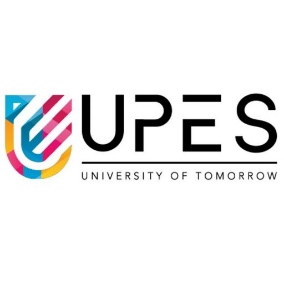
**COMPUTER SCIENCE & ENGINEERING**

**by**

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**CANDIDATE’S DECLARATION**

We hereby certify that the project work entitled **HUMAN-ANIMAL CONFLICT** in partial fulfilment of the requirements for the award of the Degree of BACHELOR OF TECHNOLOGY in COMPUTER SCIENCE AND ENGINEERING with specialization in DevOps and CCVT and submitted to the Department of Systemics, School of Computer Science, University of Petroleum & Energy Studies, Dehradun, is an authentic record of our work carried out during a period from **January 2025** to **May 2025** under the supervision of **Dr. Saurabh Shanu, SG**

The matter presented in this project has not been submitted by us for the award of any other degree of this or any other University.

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date: \_\_\_\_\_\_\_\_\_\_\_\_\_2025  **Dr.Saurabh Shanu**

Project Guide

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**ABSTRACT**

Human-wildlife conflict (HWC) has emerged as one of the most critical challenges in the conservation of biodiversity, particularly in ecologically rich yet densely populated regions like the Terai Arc Landscape (TAL). This landscape, spanning across the lowland regions of northern India and southern Nepal, forms a vital corridor that connects 14 major protected areas. These include Rajaji Tiger Reserve, Corbett Tiger Reserve, Dudhwa National Park, Pilibhit Tiger Reserve, Valmiki Tiger Reserve, Bijnor Forest Division, Kishanpur and Sohagibarwa Wildlife Sanctuaries, as well as Nepal’s Shuklaphanta and Bardia National Parks. The region supports endangered megafauna such as the Bengal tiger, Asian elephant, and greater one-horned rhinoceros, while simultaneously sustaining millions of people living in close proximity to forested zones. The frequent interface between wildlife and humans in this shared space makes conflict inevitable and often severe.

This project seeks to develop a spatial decision-support tool that can identify and visualize high-risk areas for human-wildlife conflict within this transboundary region. By leveraging geospatial techniques such as conflict heatmaps, this tool aims to assist conservationists, park managers, forest departments, and local communities in implementing more informed and targeted mitigation strategies. Using a grid-based approach, spatial data including historical incident reports, species movement corridors, proximity to water sources, and village buffers are layered and analyzed to compute conflict intensity scores across the landscape. These scores are then translated into heatmaps — color-coded visual representations that clearly highlight hotspots of human-wildlife conflict.

As a proof of concept, the methodology was initially applied to Bardia National Park in Nepal, utilizing structured data converted into a 60x80 cell grid, with each cell reflecting a conflict score ranging from 0 to 4. The generated heatmap demonstrated clear clustering of conflict in regions close to human habitation and agricultural zones. This framework is scalable and will be replicated across the other protected areas in the TAL, enabling a comparative understanding of spatial conflict trends across the entire corridor. Each area’s conflict pattern will be individually visualized and then analyzed collectively to develop a landscape-level risk management strategy.

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**1. INTRODUCTION (Chapter)**

* 1. **Background**

Human-wildlife conflict (HWC) refers to interactions between wild animals and human populations that result in negative outcomes such as injury, death, or damage to property and livelihoods. With increasing population pressure, agricultural expansion, and infrastructure development near forest fringes, HWC has escalated significantly. In India and Nepal, forest-adjacent communities frequently encounter elephants raiding crops, tigers attacking livestock, and leopards entering settlements. These incidents not only affect local livelihoods but also pose serious challenges to wildlife conservation.

The Terai Arc Landscape (TAL), spanning the Himalayan foothills from the Yamuna River in India to the Bagmati River in Nepal, is a biodiversity-rich region that supports significant populations of large mammals such as tigers, elephants, rhinos, and leopards. However, it is also home to over seven million people who rely on these landscapes for farming, grazing, and forest resources, thus making conflict an everyday concern.

**1.2 Problem Statement**

The Terai region supports several large mammals including Bengal tigers, Asian elephants, leopards, and rhinoceroses. Increasing proximity between wildlife habitats and human settlements has led to more frequent and severe conflict incidents, which include crop damage, livestock loss, and sometimes even human and wildlife fatalities. Traditional monitoring methods have not provided scalable, real-time solutions.

**1.3 Importance of Conflict Mapping**

Visual tools like heatmaps can identify conflict-prone zones, enabling better planning for fences, community outreach, patrolling, and insurance schemes. When backed by data, these visualizations can also serve as persuasive evidence for funding agencies and policy makers to support mitigation programs. Traditional reporting methods lack spatial clarity, whereas heatmaps offer intuitive and actionable insights.

**1.4 Overview of the Terai Arc Landscape**

The TAL comprises 14 protected areas including Rajaji, Corbett, Dudhwa, Pilibhit, Valmiki, and their Nepalese counterparts like Bardia and Shuklaphanta. It spans an area of over 50,000 square kilometers, featuring diverse ecosystems such as sal forests, grasslands, riverine habitats, and wetlands. The region is an ecological corridor critical for tiger and elephant movement across India and Nepal. TAL has been identified by conservation organizations such as WWF and the Wildlife Institute of India (WII) as a global priority landscape for conservation.

**1.5 Research Questions**

* Where are the most intense zones of human-wildlife conflict within the Terai Arc Landscape?
* Can a grid-based heatmap system effectively represent conflict risks?
* How can this model be adapted for landscape-level conservation planning?

**Chapter 2 – Literature Review**

**2.1 Previous Studies on Human-Wildlife Conflict**

Studies from India and Nepal have highlighted the growing trend of HWC, especially around buffer zones of protected areas. Reports from WWF, NTNC, and state forest departments document recurring incidents, but lack geospatial interpretation.

Studies conducted by the Wildlife Institute of India (WII), World Wildlife Fund (WWF), and National Trust for Nature Conservation (NTNC) have shown that HWC is on the rise across India and Nepal. For instance, Mishra et al. (2017) reported that over 1,500 conflict incidents occurred in Uttarakhand alone between 2010 and 2015. Similarly, Shrestha et al. (2020) documented increasing elephant raids and tiger attacks in the buffer zones of Bardia and Shuklaphanta National Parks in Nepal.

**2.2 Use of GIS and Heatmaps in Conservation**

Geographic Information Systems (GIS) are widely used in wildlife ecology to map habitats, corridors, and population distributions. Heatmaps are a visualization technique used to show intensity or density of data over a specific area. In Kenya, for instance, the Amboseli Elephant Research Project used heatmaps to map conflict zones near crop fields. Similarly, a study in Sri Lanka used grid-based modeling to predict elephant movement and potential hotspots.

**2.3 Landscape-Level Conflict Management**

Organizations like WII, WWF-India, and NTNC have emphasized the need for landscape-level approaches rather than park-centric management. This ensures that interventions consider animal movement patterns, ecological connectivity, and human behavior.

**2.4 Gaps in Current Approaches**

While conflict databases exist, few efforts have transformed them into visual decision-support tools. There is also a lack of predictive modeling and automated risk alerts that could help in real-time conflict prevention.

**Chapter 3 – Objectives and Scope**

**3.1 Primary Objective**

To develop a spatial model using heatmaps and machine learning algorithms that can visualize human-wildlife conflict risks across the Terai Arc Landscape.

**3.2 Sub-objectives**

* Collect and preprocess conflict data from selected protected areas.
* Generate heatmaps based on a grid-based scoring method.
* Interpret visual data for ecological and social insights.
* Propose a scalable model for regional application.

### 3.3 Scope of Study

### The scope includes protected areas of both India and Nepal within the Terai Arc. The study spans various landscapes — forest interiors, buffer zones, and transitional areas with high human activity. Each park, such as Rajaji, Corbett, Dudhwa, Pilibhit, and Bardia, offers distinct patterns of interaction due to differences in topography, species behavior, and land use. We hypothesize that high-conflict areas can be spatially predicted using historical data, and that risk is concentrated near ecotones such as village-forest interfaces, riverbanks, and crop fields adjacent to forested areas.

### Chapter 4 – Study Area: Terai Arc Landscape

### 4.1 Geographical Extent

### The Terai Arc Landscape stretches across the Himalayan foothills from Uttarakhand in India to eastern Nepal. It includes 14 protected areas and numerous corridors that facilitate the movement of wildlife across political boundaries. The terrain is characterized by alluvial floodplains, dense sal forests, grasslands, and river systems such as the Yamuna, Ganges, Sharda, and Rapti.

### 4.2 Key Protected Areas

### Shuklaphanta NP & Bardia NP: Western Nepal; transboundary connectivity with Indian reserves, key for tiger and elephant movement.

### Chitwan NP: Central Nepal; core habitat for rhinos and tigers, part of the Terai Arc Landscape.

### Parsa NP: Adjacent to Chitwan; supports dispersal and corridor functionality for large mammals.

### Koshi Tappu WR: Eastern Nepal; important for wetland biodiversity and seasonal elephant movement.

### 4.3 Socio-Economic Factors

### Communities in TAL primarily depend on agriculture, cattle rearing, and forest products. Marginalized groups often live in closer proximity to forest edges, increasing their exposure to conflict. Seasonal migration, land tenure issues, and limited awareness also exacerbate the problem.

### 4.4 Historical Conflict Trends

### Based on available records and community feedback:

### Elephant raids increase in monsoon and harvest seasons.

### Tiger attacks on livestock are more common during dry months.

### Leopards often stray into towns and villages at night.

### Chapter 5 – Methodology 5.1 Data Collection Data for this project was sourced through a combination of: - Government reports and HWC databases from forest departments in India and Nepal - Scientific literature and case studies - Data shared by conservation NGOs like WWF, NTNC, and WII - Community-level conflict reports and spatial GPS data where available Each incident was geotagged (where possible) and recorded with metadata including species, time, severity, and type (e.g., crop damage, livestock loss, human injury). 5.2 Grid Mapping and Cell Division Each national park or reserve was segmented into a grid of uniform cells (e.g., 60 rows x 80 columns for Bardia). This approach mirrors remote sensing pixel analysis and allows for heatmap computation. A grid cell was assigned coordinates (i, j) with a conflict score derived from incident frequency and severity.

### This enables: - Visualization of spatial clustering - Statistical correlation with ecological and socio-economic data 5.3 Conflict Scoring System A scoring rubric was applied to standardize data: - 0: No incidents - 1: Minor property/crop loss - 2: Livestock loss - 3: Human injury or recurring property damage - 4: Human fatality or frequent multi-species incidents This ordinal scale translates subjective reports into quantifiable values suitable for visual mapping.

### 5.4 Data Preprocessing Steps involved: - Converting raw reports into structured tabular format (CSV) - Cleaning missing data and resolving spatial inaccuracies - Normalizing date and time fields - Binning locations into grid coordinates using spatial transformation 5.5 Visualization Tools Data was visualized using tools that allow for geospatial heatmap creation. Key Python libraries like `matplotlib`, `seaborn`, and `plotly` were used to represent intensity levels across grid cells. These tools supported layering and color-coding based on conflict severity. 5.6 Algorithm Design To predict human-wildlife conflict risk, a machine learning approach was employed. The following steps outline the algorithm design: Feature Selection: Based on ecological literature and expert consultation, relevant features were selected. These typically include: - Habitat Suitability Index (HSI) - Distance to protected area boundaries - Human population density - Livestock density - Land use patterns (e.g., agriculture, forest) - Elevation and slope - Proximity to water sources - Historical conflict data Model Selection:

### Several machine learning algorithms were considered, including: - Logistic Regression: For predicting the probability of conflict occurrence. - Random Forest: A robust ensemble method that can handle non-linear relationships and provide feature importance. - Gradient Boosting Machines (e.g., XGBoost, LightGBM): High-performance algorithms known for their accuracy in complex prediction tasks. The final model was selected based on performance metrics (see Section 5.7) and suitability for the data. Model Training and Validation: The dataset was divided into training, validation, and testing sets. The training set was used to train the selected model, the validation set was used for hyperparameter tuning, and the testing set was used to evaluate the model's predictive performance. Conflict Risk Prediction: The trained model was used to predict the probability of conflict occurrence for each grid cell. This probability was then translated into a conflict risk level (e.g., low, medium, high) based on predefined thresholds. 5.7 Model Evaluation The performance of the conflict risk prediction model was evaluated using the following metrics: - Area Under the Receiver Operating Characteristic Curve (AUC-ROC): Measures the model's ability to discriminate between conflict and non-conflict areas. - Precision and Recall: Assess the model's accuracy in predicting conflict events. - F1-score: The harmonic mean of precision and recall, providing a balanced measure of accuracy. - Confusion Matrix: Visualizes the model's performance in terms of true positives, true negatives, false positives, and false negatives. 5.8 System Implementation The methodology was implemented using a combination of Python libraries, including: - Pandas: For data manipulation and preprocessing. - Scikit-learn: For machine learning model training and evaluation. - Matplotlib and Plotly: For data visualization. - Streamlit: For creating the interactive web application. The system consists of two main components: - Data Processing Module (Data Processing.py): This module performs the data collection, preprocessing, HSI calculation, and synthetic data generation. - Interactive Dashboard (wildlife\_conflict\_dashboard.py): This module provides a user-friendly interface for exploring the data, visualizing conflict risk, and running simulations. 5.9 Limitations The study has some limitations: - Data quality and availability: The accuracy of the results depends on the quality and completeness of the source data. - Synthetic data: The use of synthetic conflict data introduces some uncertainty, although it helps to address data scarcity. - Model assumptions: The HSI calculation and conflict risk prediction model rely on certain assumptions about species-habitat relationships and conflict drivers. 5.10 Future Research Future research directions include: - Improving data collection methods and integrating additional data sources. - Refining the HSI model and incorporating more sophisticated ecological factors. - Exploring advanced machine learning techniques, such as deep learning, to improve prediction accuracy. - Conducting field validation of the model predictions.

### Chapter 6 – Heatmap Generation and Visualization

### 6.1 Purpose of Heatmaps

### Heatmaps are intuitive representations of data intensity over a given area. In this project, they translate numerical conflict scores into color-coded risk zones.

### This serves multiple purposes:

### Quick identification of hotspots

### Comparative analysis across years/regions

### Resource planning for patrols, awareness, and mitigation

### 6.2 Visualization Pipeline

### The following pipeline was followed:

### Preprocessed conflict data was read into a 2D matrix

### Scores were aggregated per cell based on severity

1. X and Y axes were labeled with grid coordinates; color bar was added to indicate score levels

### 6.3 Case Study: Bardia National Park Heatmap

### The heatmap for Bardia NP reveals:

### High conflict concentration along the southern boundary (adjacent to settlement belts)

### Moderate zones near rivers and seasonal migration paths

### Very low conflict zones in forest interiors

### 

### Chapter 7 – Challenges and Ethical Considerations

### 7.1 Data Limitations

### A major challenge in creating conflict heatmaps is the availability and reliability of incident data. In many regions, conflict events go unreported, or are recorded in inconsistent formats. Some records are anecdotal, while others are poorly geotagged, making spatial modeling difficult. Lack of standardized databases across state lines or between Indian and Nepalese authorities further complicates landscape-level analysis.

### 7.2 Technical Challenges

### Although heatmaps provide intuitive insights, their accuracy depends on robust preprocessing and grid calibration. Choosing an inappropriate grid resolution can either overgeneralize or overfit the spatial patterns. Furthermore, integrating real-time data (like sensor-based detection or satellite monitoring) remains a technical barrier due to hardware costs and network coverage in remote areas.

### 7.3 Community Sensitivities and Data Ethics

### Displaying conflict-prone villages on public maps may lead to stigmatization or misinterpretation. Community members may resist external involvement if they fear legal restrictions, compensation delays, or media attention. Ethical handling of such data is vital. Data should be anonymized, and maps should be presented in formats that aid, not penalize, affected communities.

### 7.4 Ecological Ethics and Unintended Consequences

### Spatial conflict tools must not lead to harmful interventions like unnecessary fencing, relocation of species, or exclusion of traditional forest users. Any conservation plan must align with ecological science and social justice, ensuring that both biodiversity and local livelihoods are protected. Conflict mitigation must not come at the cost of ecological fragmentation or community displacement.

### Chapter 8 – Conclusion and Future Scope

### 8.1 Summary of Findings

### This project developed a geospatial framework for mapping human-wildlife conflict using heatmaps in the Terai Arc Landscape. By converting conflict incidents into spatially distributed grid scores, we created visual tools that identify high-risk zones and offer actionable insights for wildlife managers and policymakers. The method was demonstrated using Bardia National Park and is designed to be applied across Rajaji, Corbett, Dudhwa, Pilibhit, Valmiki, and other reserves in the region.

### 8.2 Applications and Stakeholder Benefits

### Forest departments can use the maps for targeted patrolling and fencing.

### NGOs can prioritize community awareness programs based on risk zones.

### Researchers can use the tool to identify long-term ecological stressors.

### Communities can engage with data to advocate for compensation or mitigation.

### 8.3 Future Enhancements

### 1.Real-Time Integration: Incorporate GPS-collared animal data, sensor alerts, and drone feeds.

### 2. Mobile Applications: Build lightweight apps to allow rangers or villagers to report incidents directly.

### 3. Cross-Border Collaboration: Design shared dashboards for Indian and Nepalese agencies.