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HUMAN-ANIMAL CONFLICTS: BRIDGING GAPS TOWARDS SUSTAINABLE CO-EXISTENCE ROLE OF TECHNOLOGY AND DATA IN CONFLICT MITIGATION

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- **Abstract-**

Human-animal conflict is a growing conservation challenge in regions where expanding human settlements border sensitive ecosystems. These conflicts are complex ecological issues, but at their heart are human stories of farmers losing crops and livelihoods, communities feeling unsafe, and endangered species struggling to survive in shrinking habitats. In this intricate dance, technology and data have begun to emerge as powerful tools in the search for solutions and peaceful coexistence. Enhanced satellite imagery, GPS tracking, and drone surveillance are providing researchers with high-resolution data on animal movement patterns like never before. Conflicts are being reimagined as opportunities on a vast map of movement, where predictive modeling tools powered by artificial intelligence are beginning to forecast migration routes and identify hotspots of potential conflict, leading to pre-emptive action rather than costly and time-consuming reactive responses. Data can also reflect the human dimensions of the problem. Platforms for crowdsourced reporting and participatory mapping can bring the often-overlooked voices of local communities into conservation dialogues, ensuring that conflict mitigation strategies are not solely driven by academic knowledge but also by people lived experiences. By merging scientific data with local knowledge, technology can become an effective bridge between people and the natural world. But with these advancements come their own sets of challenges: data gaps, unequal access, and even privacy concerns that remind us that the solutions must be equitable and mindful of both human and wildlife needs. In the end, the use of technology and data in conflict mitigation isn't about domination. It's about harnessing tools to foster understanding, resilience, and coexistence. Used thoughtfully, these innovations can rewrite the narrative of human-animal conflict from one loss and despair to one shared survival. They are a reminder that the future of conservation lies not only in the wonders of technology but also in the power of human compassion and collaboration.

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- **Introduction-**

The maintenance of ecosystem processes, functions, and the ongoing provision of ecosystem services-the cornerstones of human societies' livelihood of security, health, and general well-being-requires biodiversity. In addition to the fact that the loss of biodiversity and the ensuing loss of ecosystem services have far-reaching effects on human communities' livelihoods and general well-being, conservation of biodiversity, including wildlife, is crucial for India because of the country's cultural heritage, which views coexistence as a natural way of life. However, things are starting to change in India. Natural ecosystems are being degraded and fragmented because of growing human populations and the ensuing demand for natural resources, putting humans and wildlife in competition for the same resources. The biodiversity and ecological well-being of Earth depend heavily on wildlife, which includes all untamed plants and animals. All uncultivated plants, animals, and microbes are considered wildlife in India under the Wildlife Protection Act of 1972. Pollination, nutrient cycling, seed dissemination, and natural pest control are just a few of the ecological services that wildlife greatly contributes to.

However, human-wildlife conflict, or conflict between humans and wild animals, has become more common because of growing anthropogenic pressures. Human-wildlife conflict is the term used to describe interactions between humans and wildlife that have negative consequences, such as harm, death, destruction of crops, loss of livestock, and retaliatory animal. Being old, this phenomenon has increased in frequency and intensity in recent decades because of growing human populations, deforestation, and climate change. These disputes are particularly severe and complicated in India, a nation with one of the biggest and densest human populations.

- **Understanding of Human-Animal Conflict-**

Human-wildlife conflict arises when a species is persecuted because it directly and repeatedly threatens human safety or means of subsistence. Conflict over what should be done to correct the issue frequently results from retaliation against the species that is accused. People and wildlife have coexisted for thousands of years, so this situation is not new, but it is growing increasingly common, serious, and pervasive, and it is a global problem for both development and conservation. Elephants, pigs, deer, primates, sharks, seals, birds of prey, crocodiles, rhinos, otters, and many more species of groupings are affected by human - animal conflict, in addition to many large carnivores.

HWC very frequently has a negative influence on the livelihoods, security, and general well-being of the people we ask for support for broader conservation objectives. It also has an impact on numerous countries that are attempting to align with and reap the benefits of conservation and development initiatives. Because the underlying cultural, political, and econ01mc facto rs that influence these conflicts are sometimes extremely complicated and poorly understood, tackling Human-Animal Conflict globally presents enormous prob lems. Human-Animal Conflicts are, in fact, just disputes between stakeholders; they might be better described as "human -human conflicts." occasionally, multiple gro ups participate as well, contributing to their diverse needs and interests.

2.2. Reason of conflict-

Human-Wildlife Conflict is not merely the result of shared spaces; rather, it is a multifaceted interaction of ecological, social, economic, and behavioral elements. The causes of Human -Animal Conflict differ by region and are shaped by land-use practices, wildlife numbers, and government regulations. Identifying the underlying causes is essential for creating effective strategies to reduce conflicts. Large land-based carnivores are more likely to come into conflict as they need space and resources that are frequently diminished due to increasing human presence. Likewise, herbivores attacking crops is primarily a consequence of limited natural food sources and the fragmentation of their habitats.

2.3. Climate Change-

Climate change serves as a major indirect factor contributing to human-wildlife conflict (HWC) by modifying ecosystems, disrupting food webs, and altering migration patterns. Irregular rainfall extended dry periods, heatwaves, and increased occurrences of extreme weather compel animals to abandon their natural environments in search of sustenance and water which indicated that prolonged droughts in central India forced elephants and other herbivores into farmlands, resulting in significant crop destruction and retaliatory actions from farmers. Likewise, tigers and leopards have been seen entering villages during the summer months when natural food sources and water supplies become scarce. Increasing temperatures can alter vegetation zones, leading to changes in forage availability. For instance, wild herbivores might start feeding on high-pro tein crops such as wheat or maize, heightening competition with humans. In coastal regions, the intrusion of saline water and rising sea levels are affecting mangrove ecosystems, forcing wildlife like crocod iles, and monitoring lizards into human-populated areas.

2.4 Development of Infrastructure-

The swift development of infrastructure, such as highways, railways, dams, power lines, and urban growth, has become a significant factor contributing to conflicts between humans and wildlife. These developments frequently intersect with areas rich in wildlife, disrupting natural movement patterns, and breaking ecosystems. Wildlife corridors and migration paths are increasingly crossed by roads and rail lines. For example, the Banarhat and Chalsa railway lines in West Bengal have gained infamy for the deaths of elephants due to collisions with trains. Likewise, highways that penetrating the Sathya Mangalam Tiger Reserve has resulted in a high incidence of road kills involving leopards and deer.

Dams and irrigation channels can obstruct traditional access to water sources, particularly during dry seasons. These barriers compel animals to travel by alternative routes that are often perilous, passing through human habitations. The installation of high-tension power lines without sufficient clearance has led to multiple fatalities due to electrocution, especially among taller animals such as elephants and giraffes. Urban expansion also plays a role in habitat intrusion. Peri-urban regions in Maharashtra and Gujarat have seen an increase in leopard sightings as forests are cleared for residential and commercial developments. Unregulated tourism facilities within and adjacent to protected areas further increase pressure on wildlife.

2.5. Strategies for resolving conflicts-

Human-wildlife conflict (HWC) cannot be completely eradicated, yet it can be efficiently managed through an integration of ecological, technological, socio-political, and community-focused methods. An approach that combines conservation goals with the safety and well-being of humans is crucial for achieving sustainable coexistence over time. The subsequent sections highlight significant strategies that have been implemented, improved, or suggested in India and other regions.

- **International Legal Policies-**

196 countries have ratified the ***Convention on Biological Diversity (CBD),*** which is the international legal framework for "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources." Encouraging measures that will result in a sustainable future is its main goal. The preservation of biodiversity is a shared human interest. Ecosystems, species, and genetic

resources are all included in the Convention on Biological Diversity's definition of biodiversity. Biotechnology is also included, both through the Cartagena Protocol on Biosafety and otherwise. It encompasses all potential fields-from science, politics, and education to agriculture-that are either directly or indirectly connected to biodiversity and its role in development.

A resolution passed in 1963 at an ***IUCN (The World Conservation Union) meeting led to the creation of CITES.*** At a summit of 80 nations in Washington, D.C., on March 2, 1973, the Convention's text was eventually agreed upon, and on March 3, 1973, it was made available for signature. On July 1, 1975, CITES became effective. The original, equally authentic versions of the Convention were deposited with the Depositary Government in the languages of English, French, and Spanish. Chinese and Russian versions of the Convention are also accessible.

Adopted by every member state of the UN in 2015, it offers a common roadmap for world peace and prosperity both now and in the future. The 17 ***Sustainable Development Goals (SDGs),*** which are an urgent call for action by all nations-developed and developing-in a global partnership, are at its core. They understand that to combat climate change and protect our oceans and forests, policies that enhance health and education, lessen inequality, and promote economic growth must coexist with efforts to alleviate poverty and other forms of deprivation.

The Ministry of Environment, Forest, and Climate Change's (MoEFCC) advisories and efforts are focused on enhancing environmental governance through sustainable resource management, climate action, and regulatory compliance, according to the search results that were supplied. Important areas include adopting Plastic Waste Management Rules, upgrading Coastal Regulation Zones (CRZ), and imposing severe penalties for environmental violations (e.g., ordering the closure of non-compliant projects). The MoEFCC also priorities strengthening state-level action capability, coordinating national legislation with international commitments (such as REDD+ and UNFCCC biannual updates), and advancing the "Mission Life" movement for personal environmental responsibility.

- **National Legal Policies-**

The Wildlife Protection Act (1972) denotes maintaining ecological and environmental security; this Act protects the nation's wild plant, animal, and bird species. The Act, among other things, prohibits hunting for a wide variety of animals. 2006 saw the most recent amendment to the Act. In 2013, an amendment bill was presented to the Rajya Sabha and referred to a Standing Committee; however, in 2015, it was withdrawn.

The primary goals of the ***Wildlife (Protection) AmendmentAct, 2022,*** which was passed to update the main Act of 1972, are to better manage protected areas and bring Indian law into compliance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). One significant modification is the elimination of the distinct, contentious "vermin" category and the rationalization of the protection levels for species through the reduction of the six current schedules to four. The central government's power is greatly increased by the amendment, which permits it to appoint a Scientific Authority and a Management Authority to oversee international trade and to control or outlaw invasive alien species.

The Forest Rights Act (FRA), 2006, also known as the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 is a significant piece of Indian legislation designed to alleviate the "historical injustice" experienced by groups living in forests. By recognizing the rights of Scheduled Tribes (FDST) and Other Traditional Forest Dwellers (OTFD) over forest land and resources, the Act, which was passed in December 2006 and went into effect on January 1, 2008, moves away from the colonial approach of treating them as encroachers and toward acknowledging them as forest custodians. The main goals are to secure land tenure, guarantee food and livelihood security, and bolster the conservation regime by giving the Gram Sabha (village assembly) the authority to oversee, safeguard, and preserve community forest resources.

- **Physical impediments-**

One of the earliest and most straightforward methods of reducing conflict is physical exclusion. These include trenches, stone walls, electric fences, solar-powered fences, and bio fences made of prickly plants like euphorbia, agave, or cacti. Electric fencing has become popular, particularly as an elephant deterrent. Although it works well in the short term, non-lethal voltage settings, community ownership, and routine maintenance are necessary for its long-term effectiveness. Determined animals frequently breach poorly maintained fences, which can also endanger humans and non-target species.

- Beneficial effect - (a) Aids in comprehending animal behavior.

- Improved collaboration between humans and animals; for instance, the Maldhari population in Banni grassland has coexisted with Asiatic lions, while the Bishnoi community worships blackbuck.

- Adverse effects- (a) Animal and human deaths (b) Animal-to-human transmission of zoonotic diseases, such as Covid, Ebola, etc.

- **New developments in technology-**

To support monitoring, prediction, and mitigation, new technologies have been integrated in response to the increasing complexity and frequency of Human-Wildlife Conflict (HWC). These developments offer accurate, timely insights, and economical ways to lessen conflict and support conservation initiatives.

- *GPS devices and radio telemetry-*

Global Positioning System (GPS) collars and radio telemetry devices are two of the most useful instruments for wildlife monitoring. Large creatures like elephants, tigers, and leopards are tracked in real time using these devices. Researchers and forest officials can comprehend animal behavior, migration paths, and habitat utilization by examining the spatial data. For example, seasonal migration patterns and predictable movement lanes have been identified by GPS-equipped

elephants in southern Ind ia. Additionally, radio telemetry facilitates quick reaction and rescue efforts by helping to locate animals that have wandered into human areas.

- *Traps for cameras and drones-*

Drones, also known as unmanned aerial vehicles (UAVs), have become important tools for monitoring hazardous or inaccessible terrain, especially in hilly or forested areas. Drones that are outfitted with thermal imaging sensors and high-resolution cameras can monitor poaching activities, find animals, and evaluate habitat conditions without endangering wildlife.

On the other side, camera traps are motion-activated cameras positioned in key areas such watering holes, wildlife corridors, and close to populated areas. Time-stamped photos and videos from these cameras are essential for reco rdin g the presence of wildlife, locating conflict-p rone areas, and tracking animal populations over time. Camera traps may even monitor individual animals and identify species automatically when paired with AI systems, greatly decreasing manual effort.

- *Acoustic Sensors and Infrasonic Microphones-*

Elephants use low-frequency vocalizations called infrasound to communicate, which can travel many kilometers throu gh the air and ground. To provide an early warnin g system for approach ing elephant movement close to human settlements, acoustic senso rs and infrasonic microphones have been created to detect these vocalizations in real time.

Such systems have been put in place in places like Assam and Chhattisgarh to notify forest officials and locals when herd s get close to homes or farms. These notifications, which are frequently sent out by sirens or SMS alerts, give vital advance notice for preventative actions like setting up patrol teams, lighting fire lines, or using noise deterrents to drive elephants away.

- *Artificial Intelligence and Forecasting-*

By examining massive datasets that include animal movement, land use, weather, and historical conflict events, artificial intelligence[6] (Al) and machine learn ing algorithms are increasingly being used to forecast conflict hotspots. These algorithms can provide risk maps that help officials allocate resources more efficiently and take preventative measures in susceptible places.

Predictive modeling is particularly helpful in predicting seasonal trends in conflict, such as increased carn ivore activity during cattle grazing months or surges in crop-raid ing during harvest seasons. With a total of 69 tigers, Wayland Sanctuary is home to most tigers (82.1%). Only eight tigers, or 9.5% of the overall population, live in North Wayland. With seven tigers, or 8.3 %, South Wayland has the lowest number. There are 84 tigers known to exist in all locations.

Fro m 120 in 2018 to 84 in 2023, the number of tigers in Wayanad Wildlife Sanctuary decreased by 30%. From 4,286 (1993) to 7,490 (2011), the elephant population has steadily increased; however, no recent data is available beyond 2011. Although precise numbers have not yet been released, a fresh estimate was carried out in May 2024. Up until 2011, the numbers of gaur, sambar deer, spotted deer, and wild boar increased significantly. However, there is little data available after 2011, indicating a dearth of recent thorough surveys. The most notable increase was seen in spotted deer, which went from 6,259 in 1993 to 38,391 in 2011 before falling to 11,398 in 2011.

- **Cases in India and elsewhere-**

Although human-wildlife conflict (HWC) is a worldwide occurrence, its dynamics differ according to species, geography, land-use patterns, and sociocultural contexts. India offers numerous instructive examples of conflict and cohabitation due to its large human population and rich wildlife. Selected case studies that illustrate the problems and solutions arising from various locations are presented below.

- *Conflict between People and Elephants in Karnataka and Assam-*

Asian elephants (Elephas maximus) frequently interact with human settlements and agricultural grounds in Assam and Karnataka, two of the states with the largest populations of these animals. To lessen conflict events, both states have recently put in place a variety of community-based awareness initiatives, solar-powered fences, elephant-proof ditches, and early warning systems (such SMS alerts and mobile applications). Additionally, local support for conservation efforts has grown because of programs that encourage community involvement and alternative livelihoods. As a result, in some high-conflict areas, there has been a discernible decrease in both human and elephant mortality.

- *Leopard Encroachment in Maharashtra-*

As urban growth encroaches leopard habitats, there has been an increase in human-leopard contacts in Mumbai's suburban districts, especially in Sanjay Gandhi National Park. Panthera pardus, or leopards, have adapted remarkably to urban settings, frequently feeding cattle and stray dogs. But this adaptation has resulted in regular sightings and sporadic attacks, particularly at night.

It has been successful to change management approach to emphasize cohabitation over relocation. Panic and retaliatory killings have considerably decreased because of awareness initiatives that inform locals about leopard behavior, the significance of protecting garbage and cattle, and the necessity of avoiding outdoor activities at night. Tracking individual leopards and controlling high-risk areas have been made easier with the use of camera traps and monitoring.

- **Long-Term Mitigation of Human-Wildlife Conflict Using Holistic and Intricated Approaches-**

A multifaceted, ecosystem-based approach that incorporates technological, ecological, educationai and socioeconomic elements is necessary for the long-term reduction of human-wildlife conflict. A disjointed strategy frequently produces immediate benefits but ignores the root causes of conflict.

Thus, a unified framework that incorporates sustainable development, technological innovation, community involvement [7], and legal reforms is crucial.

- **Benefit-sharing and Participatory Governance Systems-**

Participatory governance empowers local populations and increases their interest in conservation initiatives. Moreover, benefit sharing from eco-tourism, non-timber forest product (NTFP) harvesting, and conservation linked microenterprises ensure that communities regard wildlife as an asset rather than a threat. In the Sundarbans (India) and Maasai Mara (Kenya), for instance, community-based tourism programs have greatly enhanced human-wildlife relations.

- **Conclusion-**

Human-wildlife conflict in Wayanad is a complicated and urgent problem caused by a few factors, such as substantial habitat loss and fragmentation, changing agricultural practices that draw wildlife, and dynamic wildlife populations interacting in increasingly constrained areas.

This conflict has far-reaching implications, significantly harming the socio-economic well-being and safety oflocal communities while simultaneously posing serious dangers to the region's unique wildlife populations through habitat degradation, injuries, and retaliatory kills. Although some short-term relief is provided by present mitigation techniques, their overall efficacy in ensuring long-term cohabitation is still limited, highlighting the pressing need for more creative and lasting solutions.