Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

AI-Enabled Virtual Fencing for Mitigating Human–Elephant Conflict and Preventing Elephant Mortality in India: A Conceptual Framework and Policy Appraisal

Dr.A.Shaji George

Independent Researcher, Chennai, Tamil Nadu, India.

Abstract - Human–elephant conflict is one of the most urgent conservation issues in India, resulting in the deaths of people and elephants annually and causing tension between forest departments and villagers. The effectiveness of conventional mitigation measures such as physical barriers, electrified fences and trenches has been inconsistent and they have, in some instances, created new risks. In this article, we explore a new alternative a virtual fence using artificial intelligence (AI) that has been proven to work with livestock and can be adapted for free-ranging elephants. The method involves a graduated, humane cueing system, which uses a sound cue to steer animals away from danger zones before introducing any mild physical cue, in combination with satellite positioning and behaviour trained machine-learning models. The technology is explained in simple terms, its protection benefits for elephant, community and habitat are assessed and its economic, social, ethical and governance aspects are discussed. Verified mortality data from national wildlife authorities are reported to give an indication of the magnitude of the problem with caveats for provisional data. The analysis also highlights gaps in current policy implementation, identifies mistakes that can be avoided in future policy programmes and addresses research gaps that need to be filled before scaling up deployment. The article concludes that, if used responsibly, virtual fencing can be a scalable and compassionate addition to the existing toolbox of conservation tools in India, and in other elephant range countries.

Keywords: Human–elephant conflict, Virtual fencing, Artificial intelligence, Wildlife conservation, Geo-fencing, Elephant mortality, Conservation technology, Animal welfare.

1. INTRODUCTION

Asian elephant is an unusual case in India, where it is revered in religious tradition, art and as a national symbol and is also considered as a keystone species for the health of forest ecosystems. India has the largest number of wild Asian Elephant in the world, about 60% of its total population. However, this separation comes with a significant burden as the elephants habitat is increasingly being broken up by railways, roads, the spread of agriculture, mining and human habitation. Corridors are becoming more restricted and traditional migratory routes are being blocked, bringing elephants and people into increasingly close and frequent contact, with tragic consequences for both.

The impact of this conflict is in the loss of life on both sides. Elephants die on railway lines, from electrocution due to sagging or illicitly tapped power lines, in pits and snares and sometimes by deliberate poisoning by communities who are frustrated by damage to their crops. Meanwhile, humans are killed when they come in contact with elephants in fields, near water sources or on village paths. Every occurrence adds to the resentment and undermines the goodwill that is essential to conservation. The challenge is thus not only

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

ecological, but above all social, and solutions must be found that preserve the agricultural livelihoods and at the same time protect a protected species.

Physical interventions have been the mainstay of mitigation for decades. Electrified fences, concrete walls, elephant proof trenches and barrier plantations have all been used with varying degrees of success. They are costly to install, hard to keep up on large and rugged areas and often defeated by clever animals that figure out how to get past them. Poorly maintained electric fences have in some instances become tools of injury. These static methods have inspired the development of adaptive and intelligence based methods that can adapt to the ever changing nature of elephant movement.

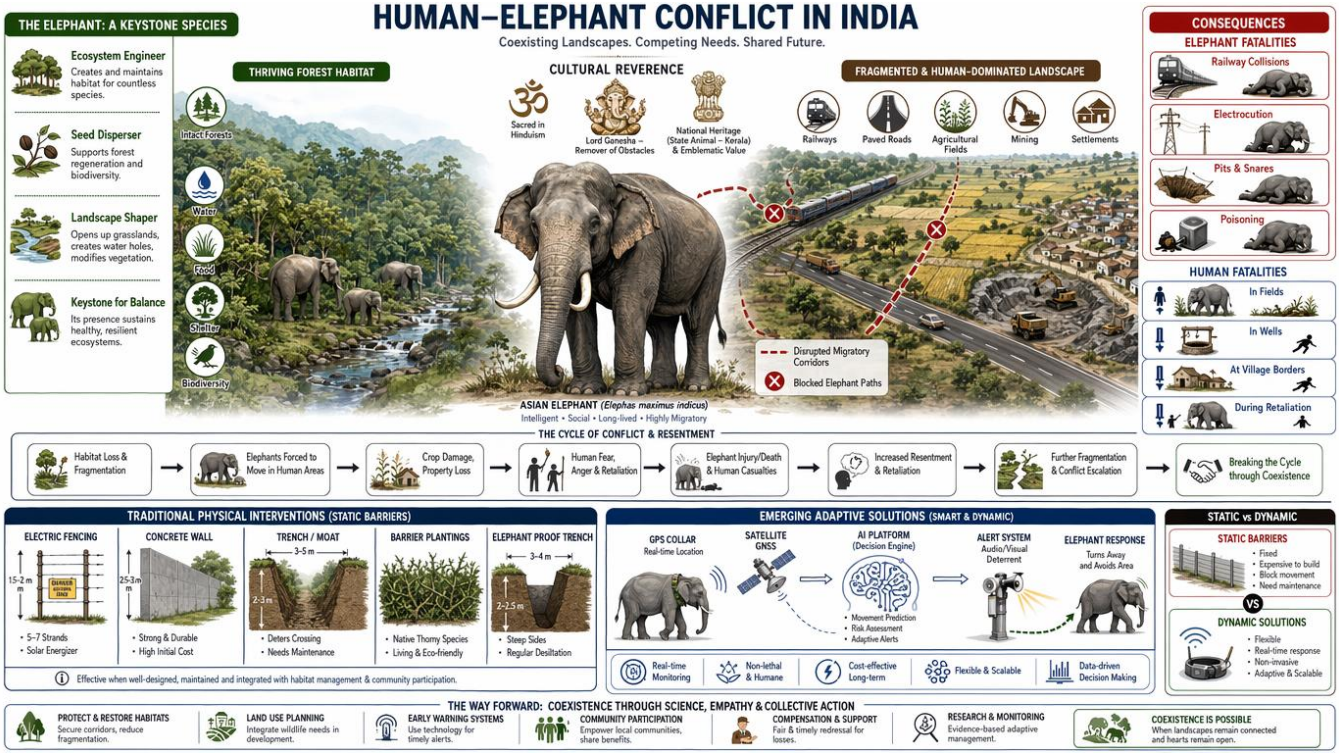

Fig -1: Human-Elephant Conflict in India

Of these new methods, one of the most promising is virtual fencing, which is already used with livestock. It is not based on solid physical barriers, but on positioning technology and behavioural conditioning to keep animals in or out of areas. Combined with AI that can learn the unique movements of individual elephants and forecast their behavior, the idea can be adapted for the much more complex requirements of wild elephants. This article examines the potential for the adaptation of such a system, its benefits and drawbacks, and how it might fit into existing conservation systems. The idea is to make government officials, forest departments, technologists and the general public aware of a tool, which, if used judiciously, could balance the conflicting needs of development, livelihood and wildlife protection in India and elsewhere.

2. OBJECTIVE OF THE ARTICLE

This article aims to provide a balanced and evidence based analysis of the use of artificial intelligence (AI) in geo-fencing to mitigate human–elephant conflict and prevent unnecessary elephant deaths in India. It aims to convey a technically complex idea to a wide audience, including policy makers, forest managers, conservation scientists, technology developers, and the general public. Another goal is to quantify the current crisis with actual death data to ensure that the discussion is based on real data and not speculation. The article also seeks to evaluate the social, economic, ethical and governance aspects of the technology, to pinpoint the limitations of existing mitigation policy, and to underscore the research gaps that need to be filled before the technology can be adopted on a large scale in a responsible manner. In the end, it aims to provide positive suggestions for future programmes in India and other elephant range countries with similar issues.

3. METHODOLOGY

This article will be descriptive and analytical, drawing from the available literature on virtual fencing and animal behaviour, peer-reviewed conservation research, and information from governmental wildlife authorities that is made public. The mortality figures are based mainly on figures provided by the national environmental and wildlife agencies and those that appear in official parliamentary records. Where figures are provisional, incomplete or based on different reporting periods, this is specifically stated to prevent any over-statement of conclusions. The technical aspects are based on known instances of the use of geo-fencing in livestock management and extrapolated with due caution to the particular physiological and behavioural traits of wild elephants. No specific products or companies are mentioned the emphasis is on principles, mechanisms and policy implications. The analysis consciously includes a variety of viewpoints, including those of affected communities, conservation practitioners, and animal-welfare advocates, to balance the analysis. The technology is not viewed as a stand-alone solution but rather placed in a larger context of existing mitigation methods as part of a comparative evaluation. The goal is, at all times, to make sure the assessment is factual, fair and of benefit to decision makers.

4. UNDERSTANDING TECHNOLOGY AND HOW IT WORKS

Virtual fencing is software-based fencing that is based on behaviour, not physical barriers. In its current livestock incarnation, an animal is fitted with a collar capable of transmitting its position, and authorities can use mapping software to set up boundaries on a screen which can be redrawn on the fly. This can be adapted to elephants but a lot of work is needed to make it work, the architecture is instructive. Digital boundaries are the basis. Protected areas, danger areas railway corridors and sensitive habitats would be defined by forest officials directly on the mapping application and could be changed quickly to take account of different seasons, crop cycles, or train schedules. This is very different from the physical infrastructure that can't be moved after it's constructed.

The humane design is around the cueing system. A wearable device is able to generate a localised audio signal as an animal reaches a predetermined threshold. If the animal persists, a mild electric pulse is given as a consequence. The sound is a gradual progression from gentle to strong so that the animal learns to associate it with the sound and may eventually respond to the sound without being physically touched. It is not intended for punishment, but for guidance and the stimulus should be well below levels which could cause harm or long-term distress.

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

AI provides the interpretation. Behaviour-trained models can determine positioning, speed, activity levels and individual movement signatures, and differentiate routine foraging from agitation or distress. Such systems can, over time, derive patterns that are correlated with feeding, water access, and overall health and can anticipate potential movement towards conflict areas before it happens, allowing for pre-emptive measures to be taken. These are all connected by a centralised monitoring platform. Authorities can use a web and app interface to have real-time visibility of herd movements, automated alerts when animals are nearing hazards, indicators of well-being and coordination of the field response. This changes the reactive crisis management approach to conservation to one of anticipatory protection.

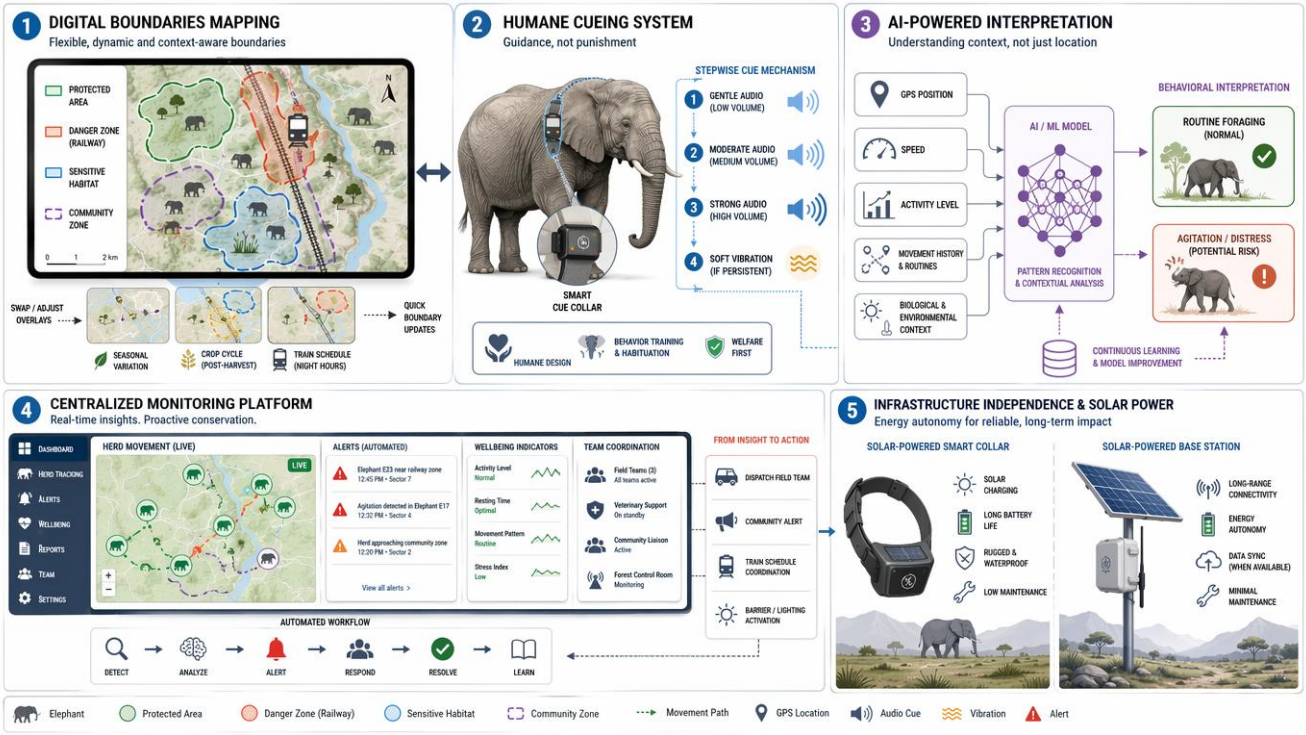

Fig -2: Understanding Technology and How it Works

Lastly, the design is not dependent on any infrastructure and uses solar power, enabling it to operate in the vast and challenging landscapes that many elephant habitats in India are characterized by, where physical fencing is difficult or impossible. The energy autonomy allows to reduce the maintenance requirements and to operate in remote areas. As a whole, these elements represent not so much a finished product but a conceptual framework that must be carefully engineered, studied in behaviour and field-validated before any reliability can be warranted for its use with elephants.

5. PROTECTING ELEPHANTS, PEOPLE, AND HABITATS

The key to the protective value of a virtual fence is that it is able to act before damage is done. Such anticipatory protection is important because of the scale of the crisis that is documented. The statistics gathered by the environment and wildlife officials of India show that approximately 186 elephants have been killed by trains between 2009 and 2020, with the last year's figures still provisional, and the previous years also likely to be revised upwards. The conservative estimates for the next decade (2016-2026) are in

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

the region of seventy to one hundred elephants. The humanmade hazards are responsible for a much greater loss of life. Electrocution due to sagging transmission lines, illegal tapping of power lines to protect crops from raids and unsafe fencing has invariably been the biggest single cause of unnatural deaths of elephants. According to national statistics, more than seven hundred elephants were killed by electrocution over the past 13 years (2009-2021), in addition to the poached and poisoned elephants. Electrocution is the leading preventable cause of death, and is the likely cause of several hundred fatalities in the 2016-26 decade.

The human toll is no less serious. Official records show that some five hundred people are killed annually by elephants, suggesting that over the past 10 years, some five thousand people have been killed. These deaths are restricted to rural and forest dependent people, whose patience with conservation efforts is not likely to be high when such deaths occur.

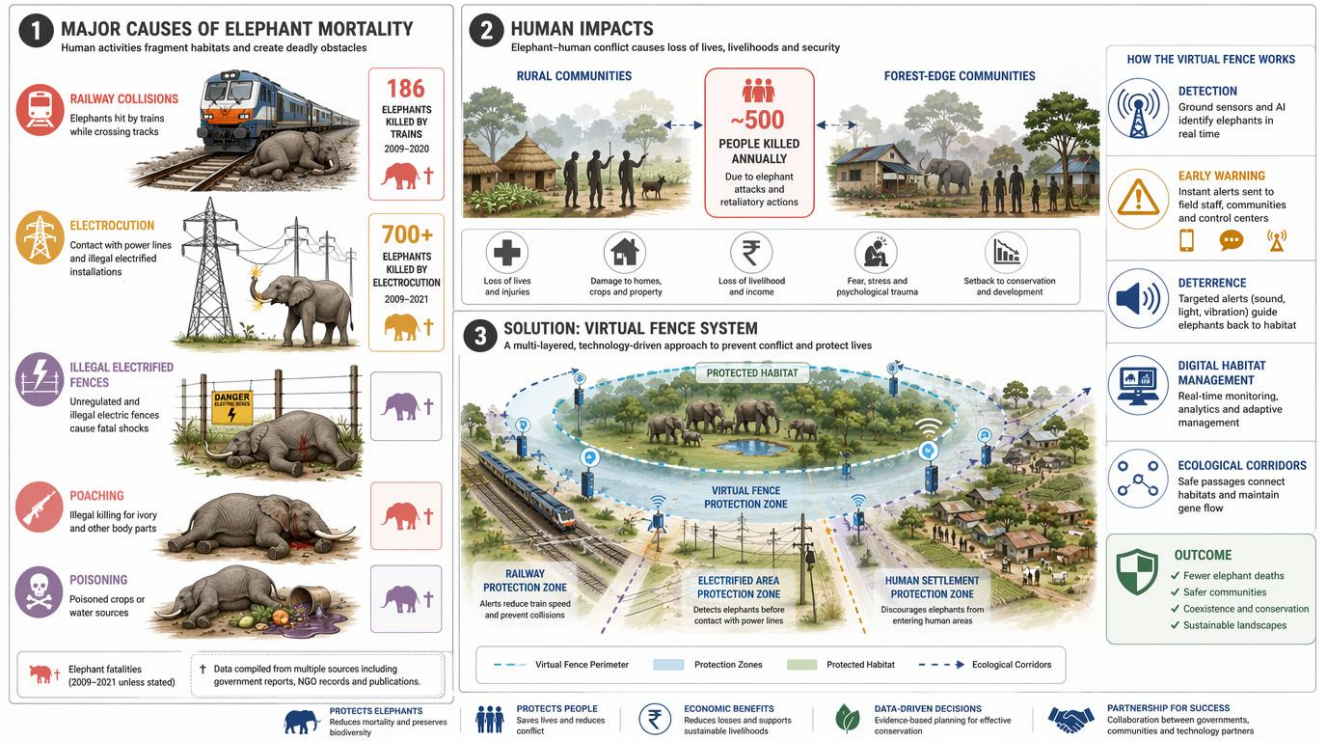

Fig -3: Protecting Elephants, People, and Habitats

It is in this context that an elephant proof system to prevent elephants from coming into contact with a railway line, an electrified area and an inhabited area is a multi-layered protection system. It makes life easier for elephants, by minimizing mechanical and electrical risks that kill the most. Early warning for people means the communities and authorities can take precautions and save lives and crops early, when they know that a herd is approaching. When it comes to habitats, the capacity to create and modify protected areas digitally allows to keep sensitive ecological areas protected and keep corridors connected without scarred landscape with permanent structures. It should be emphasized that this protection is not absolute but only probabilistic. Wild elephants are unpredictable, social and intelligent and no conditioning system can ensure compliance in all situations. The technology should thus be viewed as a significant risk reduction tool which, in conjunction with other measures, can be used to make the system safer. Its biggest

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

potential is to prevent the many deaths that could be prevented if they were not in the vicinity of a known hazard.

6. BENEFITS FOR FOREST AND WILDLIFE DEPARTMENTS

Forest and wildlife departments are constantly faced with challenges of limited staff, large areas and rough terrain. A range officer may have to monitor hundreds of square kilometers, and not have the resources to undertake continuous monitoring. With centralised monitoring, virtual fencing can make these departments much more effective and reach further.

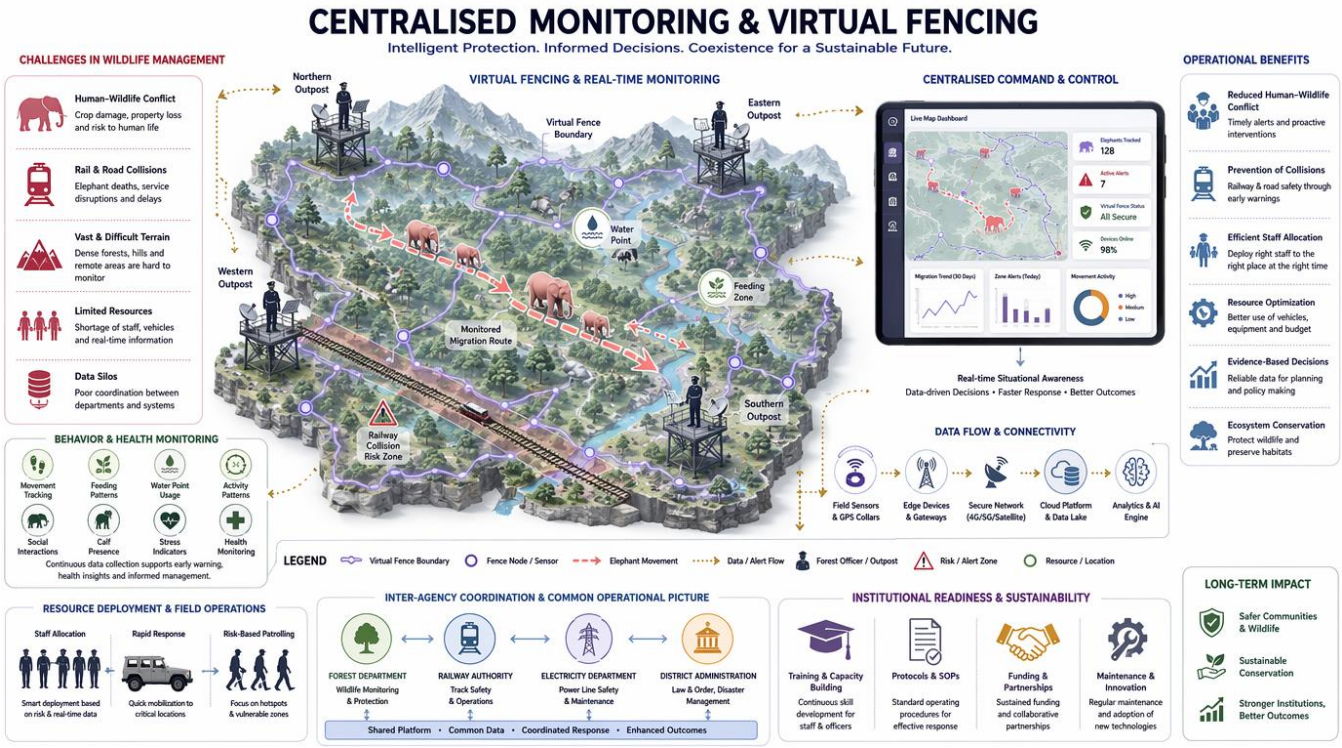

Fig -4: Centralised Monitoring & Virtual Fencing

The immediate benefit is the real time situational awareness. Officials would be able to monitor the location of herds at any time, and be alerted automatically when they move into danger or into the vicinity of human habitation. This changes the approach to field operations from reactive, after the incident, to anticipatory, set up time to avoid conflict. The allocation of resources will also benefit. Having accurate data on elephant movement patterns also enabled departments to deploy field staff more effectively, focusing effort where and when there was greatest risk, instead of having a uniform low density of field staff. Seasonal migration trends over time would enable the advance planning of harvest timing and known crossing points, in conjunction with railway operations to minimized the risk of collisions.

Another advantage of the collection of behavioural and health data. Feeding, water use, activity and movement data will accumulate over years to create a wealth of information that can be used for population management and habitat planning. This data might be useful in making decisions on protection of corridors, water-source development, and identifying specific animals that regularly trespass into conflict areas and may need targeted action. Inter-agency coordination could also be enhanced. A

common monitoring platform gives a common operational picture to forest department, railway authorities, electricity providers & district administration and facilitates common response, which has been difficult in the past due to lack of information sharing and lack of clarity of responsibility.

But these benefits require institutional readiness. There is no substitute for trained personnel, clear protocols and continued funding for technology. Capacity building of the departments would be needed to enable the field staff to read and use the data produced and maintenance would have to be arranged to keep devices and platforms working in the long term. The real danger with a sophisticated system is that it's implemented without the proper human and financial resources and turns into a barely used liability instead of an operating asset. To reap the benefits, it is important to invest in people, processes and the long-term institutional commitment that is necessary to ensure that it lasts beyond the initial window of enthusiasm that often accompanies new initiatives.

7. NEW PUBLIC KNOWLEDGE GENERATED

One of the less obvious but important products of such a system would be the knowledge base that it would develop and ideally disseminate to the public. India has long been plagued by an information deficit in conservation, where communities coexisting with elephants have a wealth of traditional knowledge, but lack systematic and real-time data on elephant movements.

Fig -5: Generating and Disseminating Public Knowledge for Elephant Conservation in India

This gap can be bridged, which can change the public attitude and behaviour. Such continuous monitoring would provide information on elephant movement patterns to a greater degree of accuracy than has been previously possible. Communities could be educated about the routes that elephants use at specific times of the year and when herds are likely to be on farmland, as well as the elephant response to seasonal

changes in water and forage. This knowledge translated into timely local warnings can then enable people to avoid dangerous encounters and to better protect crops through vigilance rather than confrontation and at the right time.

The data would also help to shed light on the real nature of conflict. Most encounters with elephants involve them trying to move across a broken landscape to find food, water and movement, and the public often views elephants as aggressors. Demonstrating that elephants are not inherently aggressive towards humans and that the main source of conflict is when they are caught off guard and approach too closely can help to promote understanding and decrease the fear and retaliation cycle. It is important to reframe in order to create the social tolerance needed for the long-term coexistence.

Anonymized and responsible release of data is a resource for students, researchers and citizen scientists. Understanding elephant behaviour, impact of habitat fragmentation, and the impact of infrastructure on elephant movement can enhance education and foster additional research. The more people are involved in conservation science, the larger the group of people who are involved in supporting conservation policy. In addition, there is an accountability aspect. If data on elephant deaths, the cause and location of deaths were transparent, the public could evaluate the effectiveness of the authorities in addressing the preventable hazards. Understanding the locations of electrocution incidents, for example, can help build a compelling argument for fixing electrical infrastructure that is unsafe and otherwise would not be addressed.

There are responsibilities with this generation of knowledge. The accurate location information of a vulnerable species needs to be treated with care so that those who might want to exploit it are not able to do so, which is discussed later in this article. Information needs to be provided in ways that can help communities and guide policy but not provide information that will help poaching or harassment. A knowledge product is a public good that, if managed properly, can be used to provide protection, but also provides other benefits beyond that.

8. SOCIAL USEFULNESS

While the prevention of human–elephant conflict casualties is important, the social value of reducing HEC is far more. Living with elephants is a constant burden of anxiety, and conflict affects communities daily lives, their freedom of movement after dark and their sense of security that is vital to rural life. The technology that can be relied upon to reduce the incidence of risky encounters can therefore enhance the quality of life beyond simply the statistics. There is significant potential to benefit agricultural livelihoods. Elephants can destroy a season's income in one night, driving vulnerable families into debt and hardship due to crop raiding. Early warning of the arrival of a herd enables farmers and authorities to take preventive measures to safeguard the harvests and the economic security which relies on them. With livelihoods in place, the need to use harmful deterrents like illegal electric fencing is reduced, thus reducing the risk to both people and elephants.

The technology could also help to rebuild relationships between communities and conservation authorities. Resentment can develop when people perceive their lives and property are being put at risk to protect wildlife, especially if there is a lack of compensation or it is slow to arrive. A system that is visible, responsive and clearly effective in keeping elephants from homes and fields, demonstrates that authorities are concerned with the welfare of the community, and this can lead to a change in attitude from reluctant tolerance to effective co-operation.

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

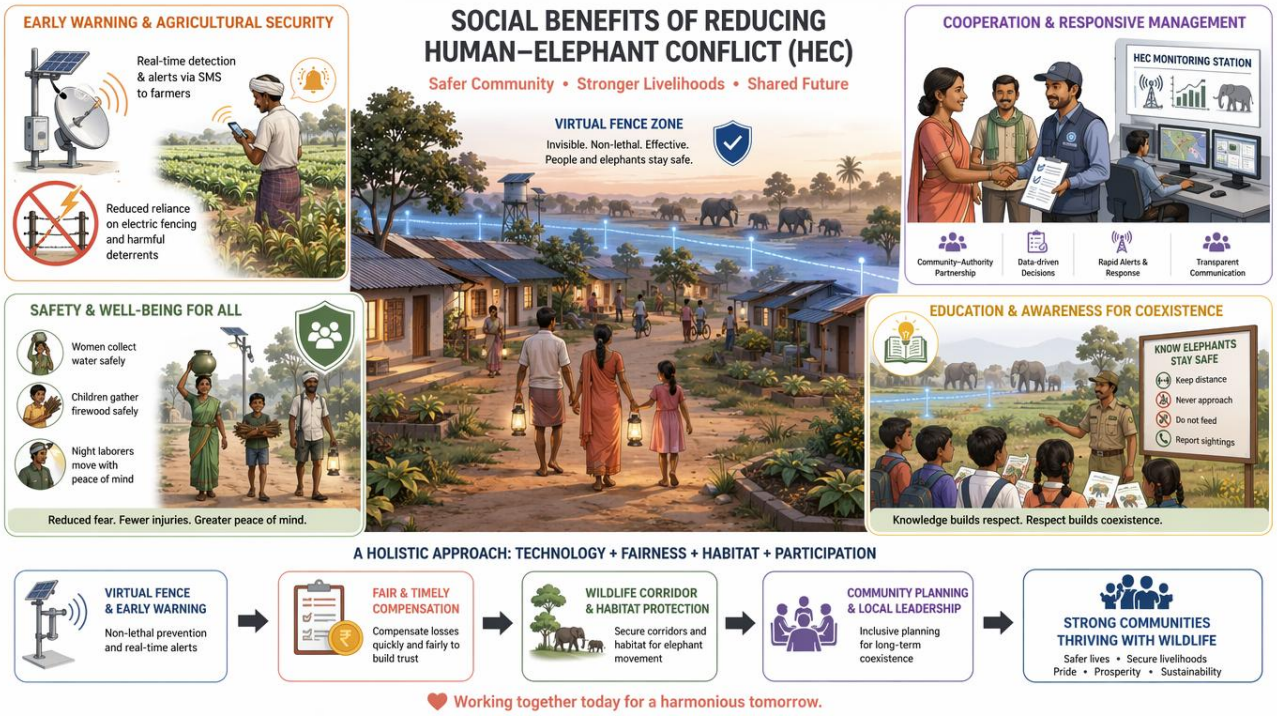

Fig -6: Social Benefits of Reducing Human-Elephant Conflict (HEC)

Special consideration should be given to vulnerable groups. Those who are most vulnerable to encountering a snake are women and children who collect firewood or water and labourers who work in fields at night. Reliable early warning gives them some protection which cannot be given to people on the move by physical barriers, fixed in place. Education and awareness is another social dividend. When communities start to learn about elephant behaviour, knowledge is likely to replace fear and coexistence is a shared task instead of an imposed one. This knowledge can help the younger generations become stewards of conservation instead of opponents.

Technology, however, should not be portrayed as a full social solution, though. Collars and software are not the answer, as the roots of conflict are habitat loss, infrastructure expansion and economic pressure. Virtual fencing should be considered a part of a wider social and ecological approach, which involves fair and timely compensation, protection of corridors and inclusive planning. In this context, it could play a valuable role in enhancing the dignity and security of the communities that have too long been taken for granted.

9. ECONOMIC AND COMMERCIAL DIMENSIONS

The economic argument for virtual fencing is based on the cost of deploying versus cost of ongoing conflict. Human–Elephant Conflict is a significant economic cost due to crop and property damage, compensation payments, lost productivity and the high costs of maintaining physical barriers which are often ineffective. As these regular expenditures are compared with an alternative that is based on technology, the overall economics can be found to be beneficial despite the initial outlay.

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

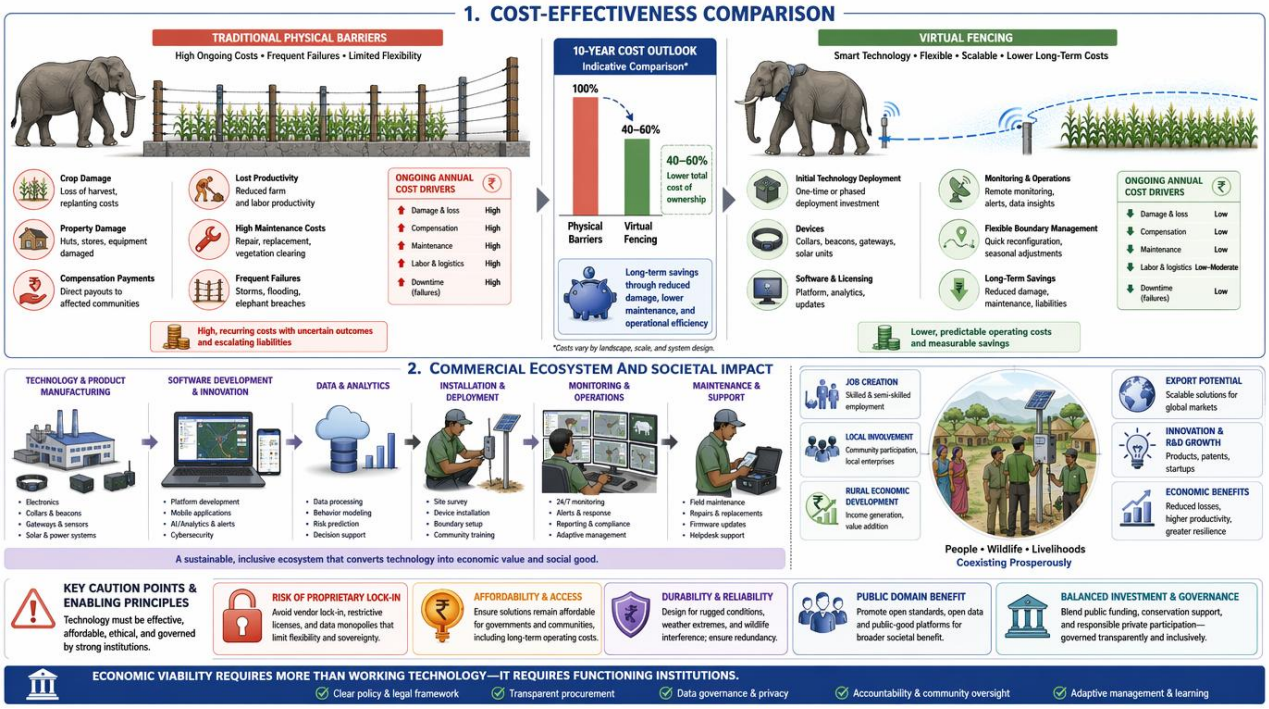

Fig -7: Economic and Commercial Dimensions

Physical mitigation infrastructure is expensive to construct and maintain, and much of the investment is wasted if barriers are overtopped or are not maintained. A virtual system, on the other hand, focuses the cost on devices, software and monitoring capacity, and the benefit is that boundaries can be changed without additional construction. Saving on crop losses, compensation claims and barrier maintenance over the years may offset the outlay, although more in-depth cost–benefit studies specific to elephants are needed to substantiate this. There would be a commercial ecosystem around such technology, including the manufacture of the devices, the software, data analysis, field installation and maintenance. This activity has the potential to create skilled and semi-skilled jobs, including in rural areas where conflict is most intense. Installation and monitoring, involving local people, would not only generate livelihoods, but also enhance the sense of ownership of the conservation activities.

There is also the economic potential in international markets. There are other countries in Asia and Africa that have similar human–large animal conflicts and a system that works well in India might be exported to those countries, making Indian expertise an export of technology and knowledge. The research and development involved could also give a boost to innovation in conservation technology in general. However, caution is still key. There is a danger that the commercialisation of conservation technology will lead to the use of technology that is more expensive than necessary, or that the technology will be so proprietary that one becomes reliant on the ongoing services of the supplier. The procurement process must be clear and based on conservation need and not commercial promotion. There is also the danger that the benefits go primarily to the technology providers and the inconvenience of involvement to the communities affected, without the benefits of it going to them. Therefore, a sound economic analysis would focus on affordability, durability and local capacity, and make sure the technology would be used to benefit public and ecological interests first. Where appropriate, a combination of public investment, conservation financing and responsible private participation should be designed to ensure long-term control and

benefit in the public domain. In short, economic viability is not just about whether the technology is working, it is about whether the institutions that procure and govern the technology are working.

10. LESSONS FOR THE FUTURE AND ERRORS TO AVOID

Past experiences with conservation technology have lessons that future programmes would be unwise to ignore. The most frequent mistake has been the scaling of unproven solutions, i.e., initiatives that are scaled up in large areas before sufficient field validation, which have failed and wasted public trust and public money. Before elephants can be widely fenced using virtual fencing, rigorous, transparent trials should be conducted in different terrain and amongst different herds to test the reliability of the method.

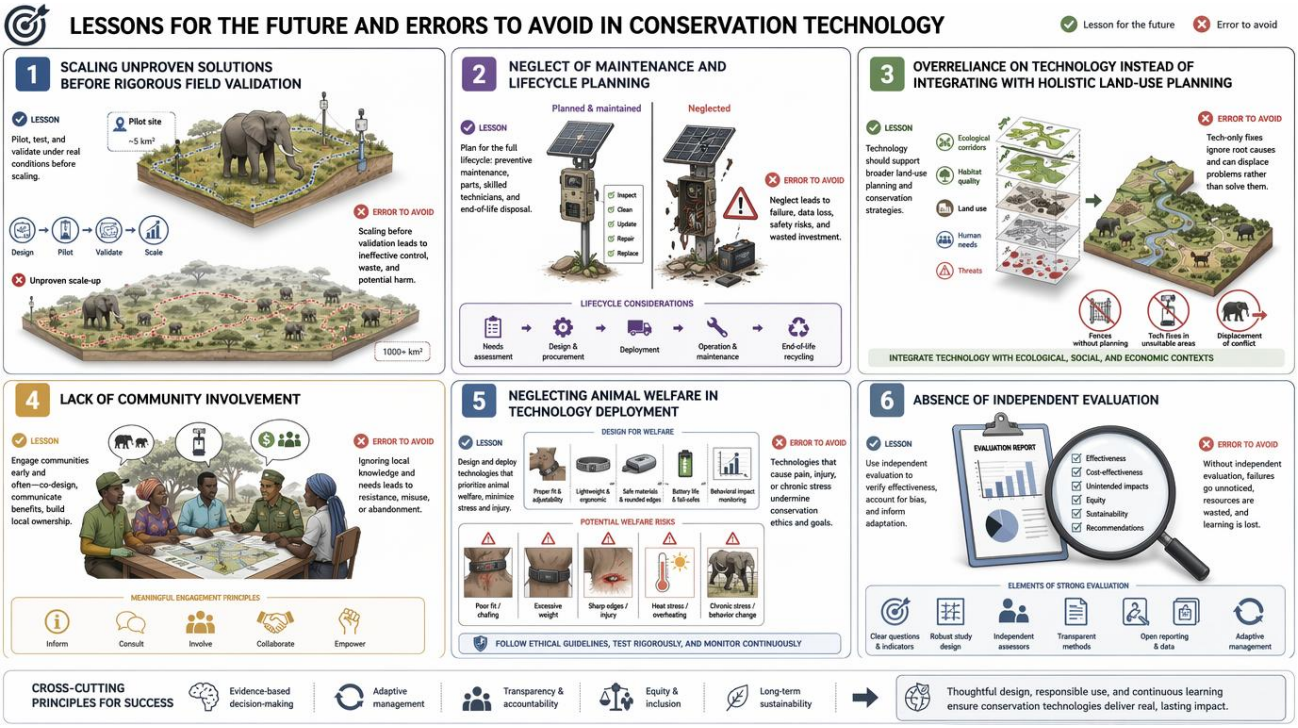

Fig -8: Lessons for the Future and Errors to Avoid in Conservation Technology

Another common error is lack of maintenance and continuity. Many good intentions have been implemented with great fanfare and then have been left to rot for a lack of funding, lost institutional interest, or lack of trained staff. Without continuous investment in maintenance, a system based on working machines, software and data connections will not work. Planning needs to therefore consider the entire lifecycle including the replacement of devices, software updates and ongoing operational support not just procurement.

A second threat is over trusting in technology as a sole solution. Three major factors that contribute to conflict are habitat fragmentation, the loss of migratory corridors and the increase of infrastructure. A symptom management system in the presence of these underlying causes will provide only a short-term fix. Future work will need to involve technological solutions in the context of broader plans for land-use planning, corridor restoration, and safe design of railways and power lines. Conservation planning has been undermined by the lack of involvement of affected communities. Local resistance can be expected to

measures imposed without local consultation and they are unlikely to be effective. Future programmes should involve communities from the beginning as partners, based on their knowledge, with benefits shared, so that protection is accepted, rather than resented.

If animal welfare is not considered during development, this would be ethically unacceptable and counterproductive. Conditioning systems need to be tested to ensure that cues do not hurt or distress animals, and that devices are comfortable and safe for animals over extended time periods. If this is not fulfilled, it would be a fair subject for criticism and might discredit the whole approach. Lastly, there has been no independent assessment, which has enabled poor projects to continue without challenge. Future programmes should include open and independent evaluation of results, based on explicit criteria, and report failures as well as successes. It is only in the face of honest recognition of shortcomings that lessons can be learned. In addition to the technical sophistication of the tools, it is important to make humility, patience and accountability part of the programme design.

11. COMPARISON WITH EXISTING MITIGATION METHODS

To appreciate the possibilities of virtual fencing, it is important to consider it in the context of current techniques, which have their own advantages and disadvantages. One of the most common interventions is the electrified fence, which can be effective in deterring elephants if it is properly maintained. However, they require constant maintenance, can be destroyed or punctured by persistent animals and have, in some cases, led to fatal electrocution due to failure or intentional misuse. They are also non-moving, which hinders the free movement that healthy elephant populations need.

There are also drawbacks to elephant-proof trenches. They are expensive to dig, become eroded and collapsed over time, become choked with debris and water, and can be crossed by elephants that learn to break through them. They also are a danger to other wildlife and must be maintained on a regular basis which is difficult for overstressed departments. Barrier plantations, which involve the use of thorny or unpalatable plants, are a more gentle and environmentally friendly alternative, but do not become effective until after several years and do not offer complete protection. Older methods like noise makers, fire and watch parties are still used, but these also put human beings in close contact with elephants and are thus dangerous and become less effective as elephants become accustomed to them.

Early-warning systems, such as those using sensors, camera or community alert networks are more recent developments and have demonstrated real potential for providing people with time to respond. These are based on the same principles as virtual fencing, in that they are about information and anticipation, but they tend to warn people not animals. In this context, virtual fencing has a number of comparative advantages. The boundaries are not hard set and can be modified without physical reconstruction. It does not impede an animal's movement, but rather gently directs them away from danger, maintaining their freedom of movement. It provides continuous data which other methods don't provide, and it is solar-powered to work in remote terrain. These characteristics overcome many of the shortcomings of traditional methods.

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

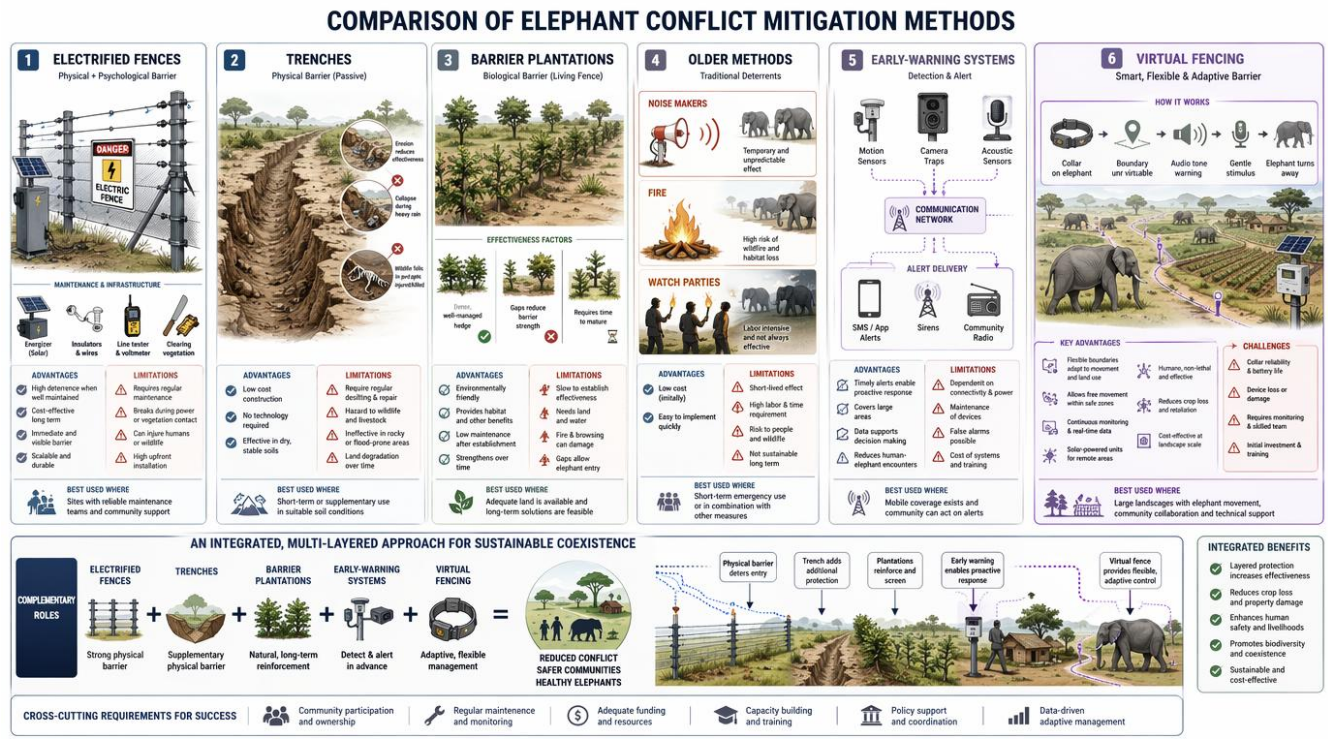

Fig -9: Comparison of Elephant Conflict Mitigation Methods

The technology also has its drawbacks, however. This requires working devices, dependable communications, and the added difficulty of securing and maintaining wearable units on wild animals, which is more difficult than on domesticated animals. It has yet to be proven to work with intelligent, social elephants on a large scale, and will not address the broader habitat loss issue. The obvious answer is that virtual fencing should not be viewed as a substitute for current techniques, but rather as an additional layer in a multi-layer approach. A good protection will probably be the one that is the most thoughtfully combined, where each tool is used in situations where it is most effective, instead of looking for a universal solution.

12. ETHICAL AND ANIMAL-WELFARE CONSIDERATIONS

An intervention which changes the behaviour of a sentient intelligent species requires a thorough ethical analysis. The elephant is a highly intelligent, socially integrated and emotionally expressive animal, making the responsibility of moving them with technology even greater. The fundamental ethical guideline has to be that any protection is to be sought without inflicting harm or unnecessary distress.

The graduated cueing system is based on this principle, and uses a soft sound cue before any actual feeling, and the animal learns to respond to the sound only. Nevertheless, the welfare consequences need to be carefully and independently validated. Research should ensure that the cues do not result in pain, fear or chronic stress, that animals can be trained to avoid the cue, and that the event does not interfere with natural social interactions and herd dynamics. Chronic anxiety would be ethically unsound conditioning that would be effective in changing movement. There are additional concerns with the physical design of wearable devices. Any unit attached to an elephant should be safe and comfortable for long periods of time, not interfere with natural behaviour, allow for growth and movement and not cause injury or irritation. The fitting and maintenance of these devices on wild animals also involves capture and

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

handling, which are also risky and stressful and must be minimized and carried out to the highest standards of care.

A more fundamental moral issue relates to the suitability of treating wild animals like they are in the control of humans. There is a philosophical issue whether or not there should be behavioural conditioning of free-ranging wildlife, no matter how benign. A compelling argument is based on an understanding that elephants already live in environments significantly altered by humans, where the only options for them are to die at the hands of a train, electrocution or retribution. In this limited reality, a humane guiding system may be the least evil that can be known, and this should be done with a humble, not certain, attitude.

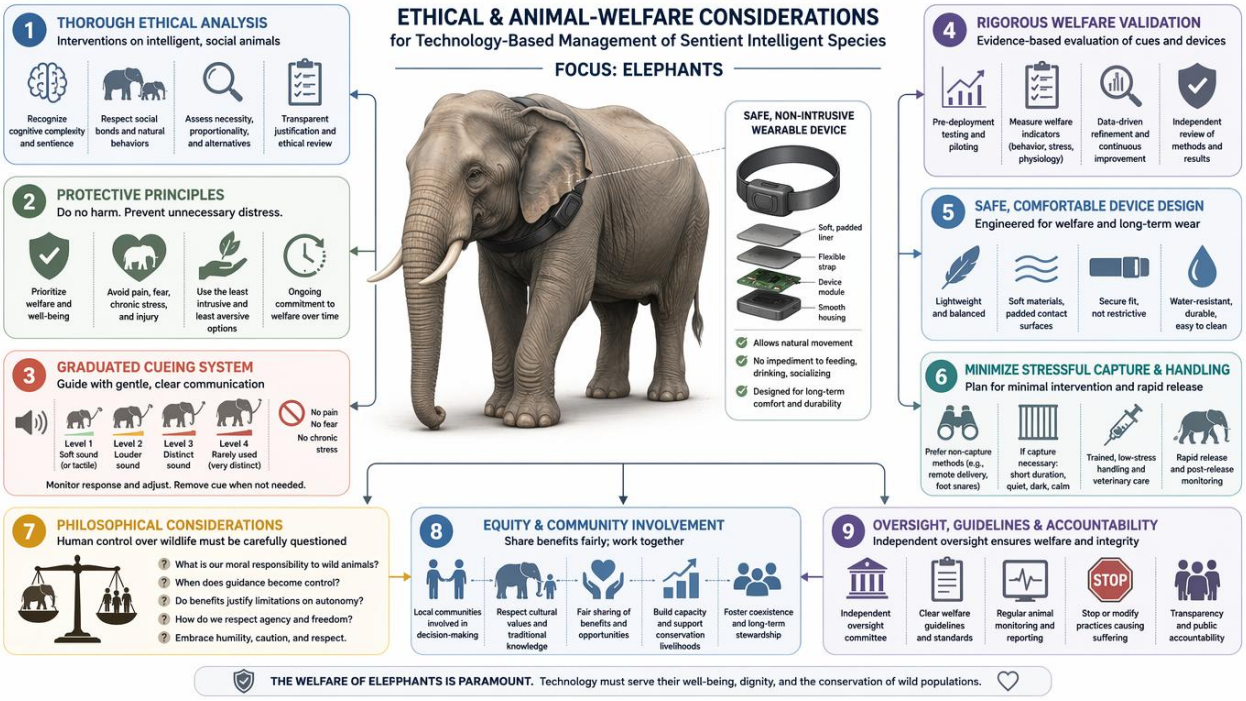

Fig -10: Ethical & Animal-Welfare Considerations

Ethical considerations also apply to equity considerations. The advantages and disadvantages of any programme should be equitably shared and the communities most impacted by conflict should not be left out of the protection technology offers, nor should they be kept out of the design. Independent oversight, clear welfare guidelines, regular monitoring of animal welfare and a true commitment to stopping or changing the practice if evidence of suffering arises are therefore essential to good practice. Technology is not enough to justify deployment – the moral obligation to the animals involved must be foremost at all stages, from research to any field deployment.

13. DATA GOVERNANCE AND PRIVACY

The ongoing gathering of fine-grained location and behavioural information adds governance issues that are easily ignored in the euphoric rush of technology, but are crucial for the legitimacy and safety of any such programme. The information produced is sensitive on two fronts first, it is about a vulnerable protected species and second, it involves communities that inhabit the landscapes that are being monitored.

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

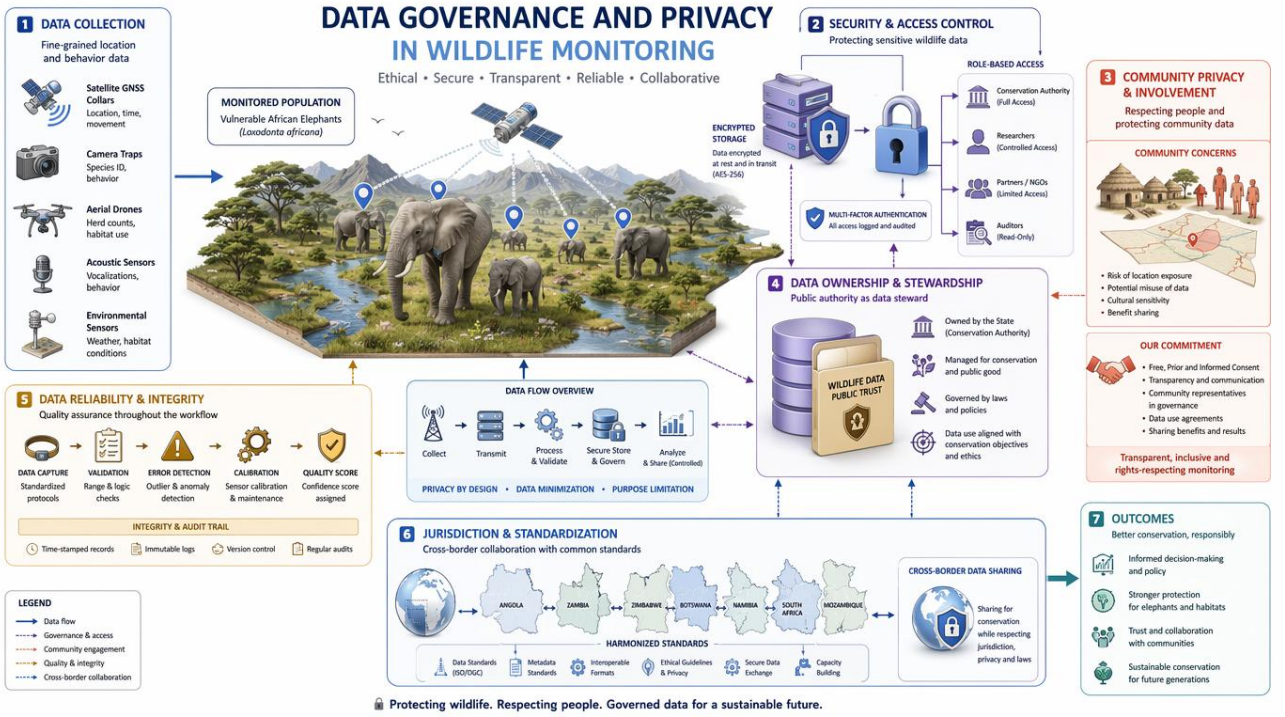

Fig -11: Data Governance and Privacy in Wildlife Monitoring

The primary issue is the security of elephant's accurate location information. Access to information on the precise location of animals especially those with valuable tusks could be very dangerous if it fell into the hands of poachers or those with other ill intent. Therefore, it is necessary to have strong security measures, such as access controls, encryption, and restricted access to detailed positioning data. Publicly released data for educational or awareness purposes should be aggregated or delayed enough as to not be used to track individual animals in real time. Ownership and stewardship needs to be clearly defined as well. The issue of who will have access to the data, what it will be used for, who owns it and for how long it will be stored must be agreed to in an open fashion prior to the introduction of any system. The potential exists that valuable data is stored privately, without proper public control, that may affect conservation priorities and accountability. The responsibility for information so closely linked to a national conservation responsibility should be kept by public authorities.

Community privacy is as important as attention. Monitoring systems designed to record animal movement in inhabited landscapes also can collect information on human activity, settlement and movement. There is a community interest in knowing what is being collected, how it is being used and what protections are in place for the community. They need to be informed and involved in governance arrangements and this is important to building trust. Another dimension of governance is reliability and integrity of data. This information would be the basis for decisions that would impact both human and animal safety, and thus, accuracy would be key. Systems need to be in place to identify and address errors, gaps and equipment failures, and operators need to be aware of the limitations of the data and not take automated alerts as gospel. If the technology were to proliferate, other issues of consistency, jurisdiction, and standards, related to cross-border and inter-agency data sharing, should be addressed. Good governance is not a secondary administrative issue, but a prerequisite for proper deployment. Even the best system can be undermined by the lack of rules, transparency and accountability.

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

14. SCALABILITY ACROSS INDIAN STATES AND GLOBALLY

The feasibility, adaptation and equity of scaling up the application of virtual fencing in the varied elephant landscape of India, and beyond, are important questions to consider. The elephant populations of India live in vastly different habitats ranging from north-east forests and tea gardens, to the central tribal areas, to the southern reserves and the north-east foothills. The physical geography, flora and fauna, climate and conflict dynamics are unique in each region, and a system that works in one place does not necessarily work in another.

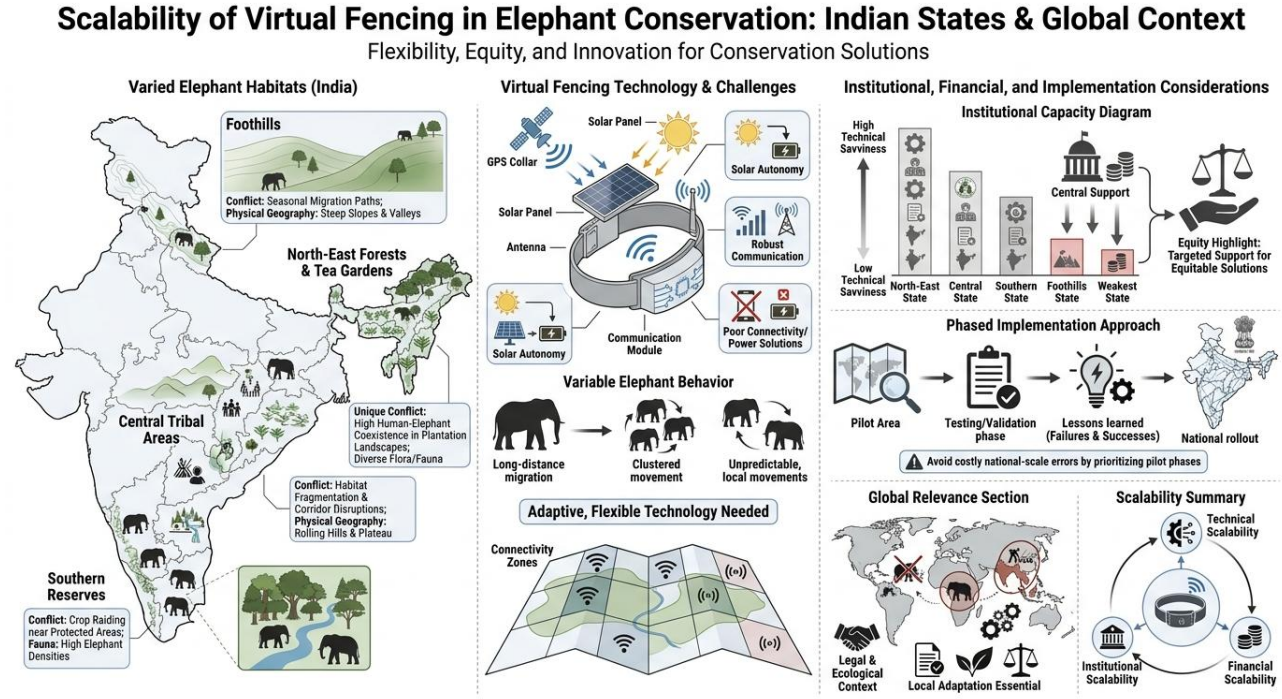

Fig -12: Scalability of Virtual Fencing in Elephant Conservation Indian states & Global Context

Scalability thus requires flexibility and not uniformity. The devices and software would have to be able to operate effectively in thick forests, open fields, hills and other zones of connectivity. Areas with poor mobile reception and or power supply are especially challenging, but solar autonomy and a robust communication design can help address some of these challenges. Behaviours of elephant populations can also vary from area to area, thus models need to be tailored to each region. There is a wide range of institutional capacity across states, with important consequences. Better resourced and technically savvy forest departments in the states could be more inclined to implement such systems, whereas others may be left behind. Equitable national progress would depend on central support, funding and technical assistance being targeted to areas with the lowest conservation effectiveness and not the highest, since otherwise the technology could exacerbate the differences in effectiveness.

The most sensible way to proceed is to do it in a phased manner. The best approach would be to start in select pilot areas that would reflect varying conditions and validate and refine the technology prior to widespread implementation. The lessons learned from initial deployments, including failures admitted, would guide further expansion and avoid the national scaling-up mistake of investing in a costly error.

The approach has a high relevance internationally. The human-elephant conflict is a problem faced by many countries in South and Southeast Asia and in other African countries where elephants are found. Such a system, if proven to work in Indian conditions, could, with suitable adaptation, help to conserve elsewhere, and international cooperation could help to speed up learning and cut costs through joint research. However, careful adaptation to local needs and conditions would be required, as differing legal frameworks, resources and ecological contexts would require it. At the end of the day, scalability is not only a technical but also institutional and financial issue. Whether the approach will be a localised experiment or a true tool of conservation at scale over many years will depend on the capacity to manufacture, deploy, maintain and govern such systems at scale.

15. POLICY RECOMMENDATIONS

To turn the promise of virtual fencing into good practice, it is necessary to have a conscious and well-planned policy sequence. The first suggestion is that adoption should be done on the basis of well-designed and independently assessed pilot programmes before it is adopted at a larger scale. These trials should be conducted under different terrain and conflict situations, should have clear criteria of effectiveness and welfare and should be transparently reported, including failures, and decisions made based on the evidence of the trials, not optimism. It is important to integrate with wider conservation strategy. Policy should consider virtual fencing as one of many measures as part of an overall strategy to focus on elephant corridor protection and restoration, safe redesign of railway lines and power infrastructure in elephant conflict zones and maintaining habitat connectivity. Technologies that treat symptoms but leave the root causes intact would only provide a short-term reprieve, and policy needs to be wary of such false hopes.

Funding mechanisms should be secured from the beginning and include not only the purchase of the devices and software but also support services for the system and staff to run it. Continuous technical capacity building, including training and recruitment, in forest departments is essential as the best system will not work without trained and competent technical capacity. Prior to deployment, clear rules of governance for the security, ownership, access and privacy of data should be established, with public authorities maintaining stewardship over sensitive data and communities being protected and consulted. Independent monitoring and oversight of animal welfare and programme effectiveness should be built in and have the power to recommend revision or suspension if evidence indicates.

The involvement of communities should be specifically addressed in policy. Affected communities should be involved from the planning phase as partners, their knowledge should be taken on board and their interests should be protected, and prompt and fair compensation for losses should be paid, in parallel to any technological measure. Coordination mechanisms between forest departments and railway and electricity authorities and district administrations should be formalised and information shared should result in joint action.

Central support should be allocated based on equity among states and focus on areas where there is the greatest need and the least capacity. International cooperation should be facilitated to share research and reduce costs and to help in conservation efforts worldwide, taking local conditions into account. Last, policy must encourage openness, flexibility, learning and adjustment, and public reporting of results, with a real disposition to learn and adapt. This recognition that current interventions have been too reactive, under-resourced and under-coordinated should herald a re-commitment to anticipatory, well-resourced and

Partners Universal Innovative Research Publication (PUIRP)
Volume: 04 Issue: 03 | May-June 2026 | ISSN: 3048-586X | www.puirp.com

humane protection. This is not a criticism to be shied away from, but one that is the basis for better stewardship to be responsibly developed in the years to come.

16. FEASIBILITY CONSTRAINTS AND THE QUESTION OF COVERAGE

An objective evaluation of the use of virtual fencing for elephants has to address a basic issue that sets it apart from the use of virtual fencing with livestock elephants are wild, many, and mostly untamed. One of the reasons that livestock virtual fencing is successful is that every animal in a managed herd can be put with a device in a controlled environment. By contrast, India has tens of thousands of wild elephants and these exist in a landscape where capture and collaring is much more expensive, risky and stressful for the elephants. Giving each person a device is impractical and undesirable, and the inevitable question arises How will a system protect against animals that it doesn't track.

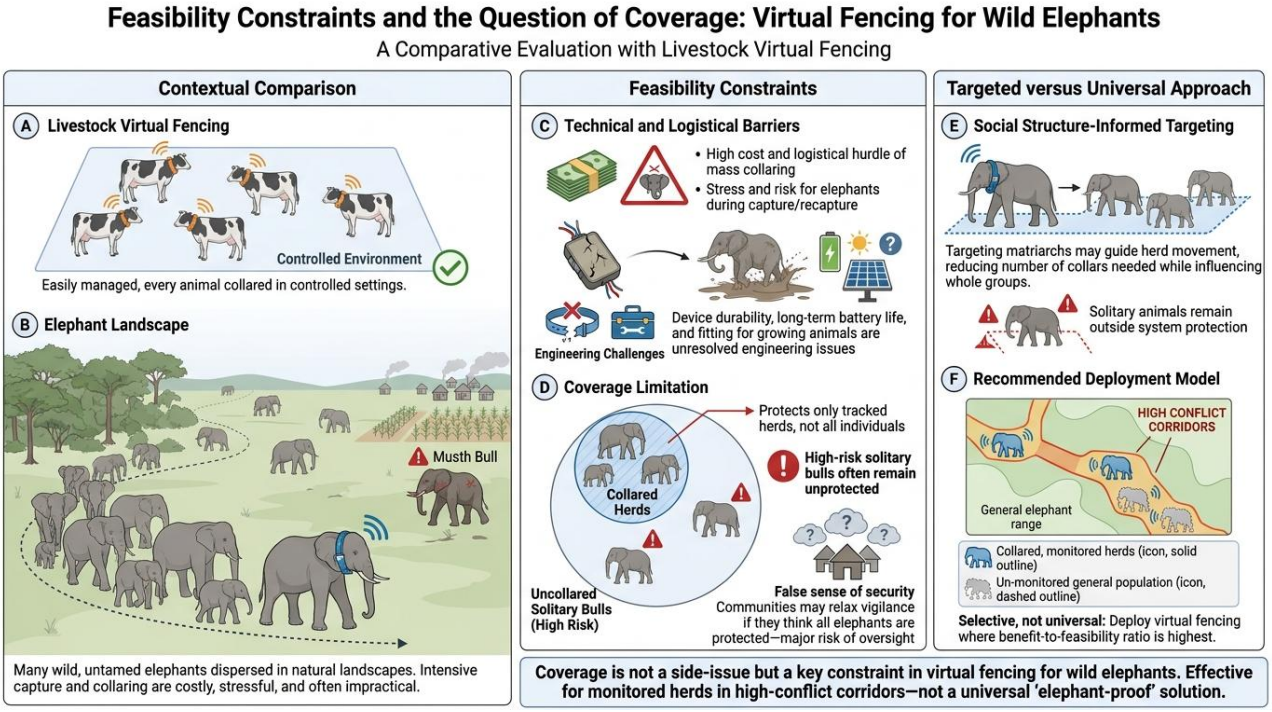

Fig -13: Feasibility Constraints and the Question of Coverage Virtual Fencing for Wild Elephants

This limitation is important as conflicts are not evenly distributed in the population. Many of the serious incidents are with solitary bulls, especially musth bulls, and those that regularly break into crops. Often these are the ones that are the most difficult to find or approach for collaring. A protective system that only works for equipped animals may therefore leave the highest risk encounters unprotected, and give communities a false sense of security, which could be hazardous if they relax. A more realistic deployment model inspired by elephant social structure. Further, experienced matriarchs lead herds and other animals follow closely behind, indicating that influencing the movement of these individuals may influence the movement of the herds as a whole without collaring every animal. This sort of targeted approach would significantly decrease the scope of the collaring challenge, but provide little protection for the solitary animals and would need careful study to ensure that the herd cohesion was maintained under behavioural guidance.

The maintenance is another limitation. Fittings on wild elephants must withstand water, mud, vegetation and elephant behaviour for long periods of time and retrieval for repair replacement re-exposes the animal to the risk of capture. The life of the batteries even with solar assistance and the durability of the fittings on an ever-growing and powerful animal are still open engineering issues. These restrictions are not the denial of the approach but they limit it. The most likely interpretation of virtual fencing is that it is a technology that can be used selectively for monitored herds in known high conflict corridors, where the benefit-to-feasibility ratio is favourable, instead of a universal elephant-proof fence across elephant range. This helps to avoid over-claiming what can be achieved with the conservation technology, which has been a problem with previous ones, and focus resources where the method can be feasible. In short, coverage is not a side-issue but a key factor in what the technology can and cannot achieve and should be dealt with forthrightly in any programme design.

17. RESEARCH GAP

However, large gaps in knowledge should be openly admitted as they are the gap between what is desired and what is achieved. The basic difference is the application: virtual fencing has been developed and tested with domesticated livestock, and there is limited peer-reviewed evidence of the effectiveness and safety of virtual fencing for wild, free-ranging elephants. The social structure, size and behaviour of elephants are very different from those of cattle, as are their intelligence, and the idea that what works for one will be effective for the other should not be taken for granted and should be tested empirically.

The closely related welfare evidence gap is another. The long term physiological and psychological consequences of the behavioural conditioning of elephants are not properly understood. There is a need for research to ensure that the cues do not harm or cause chronic stress to the animals, the animals learn the appropriate responses and that herd cohesion and natural behaviour are not affected. In the absence of such evidence, claims of humaneness are based on reasoning and not demonstration. There are still technical gaps. Further engineering studies are needed to design a device that can be safely and comfortably worn for extended periods of time on elephants, to ensure that the positioning and communication device works well in difficult environments, and to ensure that the device can be fitted and maintained on wild elephants. There is little testing of the performance of behaviour-prediction models for elephants compared to livestock, and a significant amount of species-specific data would be needed to develop such models.

Economic evidence is also weak. To make sound investment decisions, rigorous cost–benefit analyses of virtual fencing compared to existing methods, based on actual elephant deployments and not projections, are required. The social aspects, such as community reaction to the technology over time, and changes in trust and behaviour, also need systematic study. Another gap is the lack of linking up of such technology with overall conservation strategy. There is still limited research on the effectiveness of virtual fencing combined with corridor protection, infrastructure redesign, etc. and when it is most valuable. The data governance and ethical frameworks that are suitable for the wildlife conditioning context are also relatively underdeveloped and deserve to be studied and developed as a policy.

Lastly, although the mortality statistics supporting the case for intervention are indicative, there are inconsistencies in the reporting periods, definitions and completeness of data sources, and better and standardised data collection would enhance research and policy. These gaps are not a reflection on the potential of the approach, but rather the responsible course of action patient, open and adequately resourced research, rather than a large-scale deployment.

18. CONCLUSION

Human Elephant Conflict in India is a significant moral, ecological and social issue where the lives of a sacred and ecologically important species are pitted against the safety and livelihoods of vulnerable communities. The reported casualties, including elephants killed in railway accidents, electrocuted or killed by other avoidable means, and the loss of human life, in the thousands over the last ten years, make it clear that more effective and humane solutions are needed. While the figures are tentative in the most recent years, there is no doubt that current strategies, as good as they may be, have not been enough to address the magnitude of the issue.

The use of geo-fencing using Artificial Intelligence is a truly promising way. It overcomes some of the longstanding limitations of traditional mitigation by using soft, incremental electronic barriers to guide animals instead of physical ones, and by producing continuous data to anticipate animal actions. It can have a positive impact on elephant and human protection, capacity building of forest departments, creation of useful public knowledge and rural livelihoods and social trust. However, there needs to be a balance of enthusiasm and honesty about what hasn't yet been proven. The technology has been proven for livestock only, not for the intelligent and complex elephant, and the effectiveness, safety, welfare and economic viability of the technology to be adopted on a large scale in the wild needs to be thoroughly researched. It will not address the root causes of conflict habitat loss and fragmentation of corridors and should therefore be viewed as one of the elements in a layered approach.

The lessons learned from past conservation projects include that scaling up too early, lack of maintenance, exclusion of communities and lack of independent evaluation are all dangerous pitfalls. The way forward must be responsible, and it requires patience, transparency, continued support, proper data management, a commitment to animal welfare and a true partnership with the communities most impacted. It also requires honesty about the flaws in the existing management too often reactive and under resourced so that, as a result, new efforts can be anticipatory, humane and held to account. If these conditions are fulfilled, virtual fencing can make a valuable contribution to a future where elephants and humans can co-exist with much less tragedy on both sides. However, the technology itself won't do this the wisdom, integrity and commitment of those governing its use will be the deciding factor. The burden for India, who are home to the majority of the world's wild Asian elephants, is great and the chance to set a good example, through humane and thoughtful action, is one worth taking.

REFERENCES

[1] Das, G., Selvan, K., Lahkar, B., & Gopi, G. V. (2022). Effectiveness of physical barriers in mitigating human–elephant negative interactions in north-east india. Frontiers in Conservation Science, 3. https://doi.org/10.3389/fcosc.2022.956568

[2] Dhakad, M., & Saikia, N. (2023). Causes of death in india: A detailed analysis of external causes of deaths. Sustainable Development Goals Series. https://doi.org/10.1007/978-981-99-0002-2_6

[3] Dheeraj, D., & Annamaneni, G. (2024). Financial forecasting and AI. Minds Unveiled. https://doi.org/10.4324/9781032711089-17

[4] Khan, M. J., & Awais, M. M. (2025). Livestock health management using artificial intelligence based approaches in rural areas. Smart Technologies for Sustainable Livestock Systems. https://doi.org/10.1201/9781003527114-11

[5] Locke, P. (2016). Conflict, coexistence, and the challenge of rethinking human–elephant relations. Conflict, Negotiation, and Coexistence. https://doi.org/10.1093/acprof:oso/9780199467228.003.0001

[6] Maitry, A., Chandrakar, S., Shukla, A., & Chandra, A. (2023). Quantitative assessment of macrophytes diversity and their status in wetlands of guru ghasidas vishwavidyalaya, bilaspur, chhattisgarh (india). International Journal of Agricultural and Applied Sciences, 4(2), 120-127. https://doi.org/10.52804/ijaas2023.4216

[7] Sampson, C., Leimgruber, P., Rodriguez, S. L., McEvoy, J., Sotherden, E., & Tonkyn, D. (2019). Perception of human–elephant conflict and conservation attitudes of affected communities in myanmar. Tropical Conservation Science, 12. https://doi.org/10.1177/1940082919831242

[8] Stoneman, R. (2019). The trojan elephant. The Greek Experience of India. https://doi.org/10.23943/princeton/9780691154039.003.0014

[9] Sukumar, R., & Santiapillai, C. (2000). Asian elephant population estimates and distribution: 1999 update. Elephant, 2(4), 12-12. https://doi.org/10.22237/elephant/1521732189

[10] Thekaekara, T., & Thornton, T. F. (2016). Ethnic diversity and human–elephant conflict in the nilgiris, south india. Conflict, Negotiation, and Coexistence. https://doi.org/10.1093/acprof:oso/9780199467228.003.0014

[11] Waterhouse, T. (2023). Virtual fencing systems: Balancing production and welfare outcomes. Livestock, 28(5), 227-234. https://doi.org/10.12968/live.2023.28.5.227

[12] Bais, B., & Singh, J. (2018). Wildlife tracking with latest electronic technology. International International Journal of Avian & Wildlife Biology, 3(3). https://doi.org/10.15406/ijawb.2018.03.00093

[13] Chakraborty, S. (2026). Ecological analysis of drivers influencing elephant mortality from electrocution in west bengal, india. Regional Environmental Change, 26(2). https://doi.org/10.1007/s10113-026-02594-y

[14] Geetha, K., Jayanth, S., & Prakash, M. (2025). Deaths due to wild elephant attack - a case series. Sri Lanka Journal of Forensic Medicine, Science & Law. https://doi.org/10.4038/sljfmsl.v16i1.7994

[15] Humphries, G. R. W. (2018). How the internet can know what you want before you do: Web-based machine learning applications for wildlife management. Machine Learning for Ecology and Sustainable Natural Resource Management. https://doi.org/10.1007/978-3-319-96978-7_17

[16] Kalhara, T. G. D. (2025). SRI LANKA'S TRAIN-ELEPHANT COLLISION CRISIS: A REVIEW OF POLICY AND TECHNOLOGICAL INTERVENTIONS. Third Desk Research Conference. https://doi.org/10.64920/drc2025081

[17] Lundin, A. P. (1994). Many deaths in hemodialysis patients are preventable. Death on Hemodialysis: Preventable or Inevitable?. https://doi.org/10.1007/978-94-011-0806-5_21

[18] Murugadoss, R. (2025). Ai-powered monitoring for mitigating human-animal conflicts in agricultural and forest zones. 2025 International Conference on Data Science, Agents & Artificial Intelligence (ICDSAAI). https://doi.org/10.1109/icdsaai65575.2025.11011721

[19] Roy, K., Pandey, R., Athira, N., Dutta, A., Mittal, D., Nigam, P., Nath, A., & Habib, B. (2025). Long-term trends in human fatalities from human–elephant conflict in chhattisgarh, india. Scientific Reports, 15. https://doi.org/10.1038/s41598-025-13005-3

[20] (2023). Peer review #3 of "integrating robotics into wildlife conservation: Testing improvements to predator deterrents through movement (v0.2)". https://doi.org/10.7287/peerj.15491v0.2/reviews/3

[21] Chartier, L., Zimmermann, A., & Ladle, R. J. (2011). Habitat loss and human–elephant conflict in assam, india: Does a critical threshold exist?. Oryx, 45(4), 528-533. https://doi.org/10.1017/s0030605311000044

[22] Chaudhary, S. K., Pandey, A. C., & Parida, B. R. (2024). Geospatial analysis of elephant habitat suitability and movement for mapping the elephant corridor in dalma wildlife sanctuary (india). Environmental Monitoring and Assessment, 196(10). https://doi.org/10.1007/s10661-024-13110-2

[23] Deng, Y., Yuan, S., Deng, X., Chen, H., Li, Z., Guo, X., Wang, B., Campos-Arceiz, A., & Lin, L. (2025). Elephant early-warning system in china: Leveraging information superiority to mitigate human-elephant conflict. Bulletin of the Chinese Academy of Sciences, 39, 2025003. https://doi.org/10.1051/bcas/2025003

[24] Dorji, C., Chhetri, R. K., & Dorji, T. (2024). Impact of human-elephant conflict on the communities' livelihood: A study in southern bhutan. GeoJournal, 89(5). https://doi.org/10.1007/s10708-024-11184-6

[25] Jadhav, S., & Barua, M. (2012). The elephant vanishes: Impact of human–elephant conflict on people's wellbeing. Health & Place, 18(6), 1356-1365. https://doi.org/10.1016/j.healthplace.2012.06.019

[26] Locke, P. (2016). Conflict, coexistence, and the challenge of rethinking human–elephant relations. Conflict, Negotiation, and Coexistence. https://doi.org/10.1093/acprof:oso/9780199467228.003.0001

[27] Moreau, M., & Woodhouse, E. (2025). Improving transparency in conservation social science research to enhance quality, equity, and collaboration. Conservation Biology, 39(2). https://doi.org/10.1111/cobi.70003

[28] Mumby, H. S., & Plotnik, J. M. (2018). Taking the elephants' perspective: Remembering elephant behavior, cognition and ecology in human-elephant conflict mitigation. Frontiers in Ecology and Evolution, 6. https://doi.org/10.3389/fevo.2018.00122

[29] Roy, A., & Sharma, S. (2026). Elephant taking the lion's share: Political ecology of elephant conservation and human-elephant conflict in eastern india. Journal of Political Ecology, 33(1). https://doi.org/10.2458/jpe.6435

[30] (2012). Bringing conservation science to life: The role of communication to support policy influencing processes in africa. Conservation and Sustainable Development. https://doi.org/10.4324/9780203131480-15

[31] (2022). Human–elephant conflict in northern botswana. Ecological Vulnerability. https://doi.org/10.1017/9781009051958.006

[32] Aslam, H., & Munawar, S. (2023). Smart energy conservation in data centers using machine learning based software-defined networking. 2023 6th International Conference on Energy Conservation and Efficiency (ICECE). https://doi.org/10.1109/icece58062.2023.10092487

[33] Baldwin, R., Scherzinger, R., Lipscomb, D., Mockrin, M., & Stein, S. (2014). Planning for land use and conservation: Assessing gis-based conservation software for land use planning. https://doi.org/10.2737/rmrs-rn-70

[34] Barakova, A., Ussatova, O., Zhussipbekova, S., Urazgalieva, S., & Shadinova, K. (2024). USE OF BLOCKCHAIN FOR DATA PROTECTION AND TECHNOLOGY DRAWBACKS. Physico-mathematical series, 67-77. https://doi.org/10.32014/2024.2518-1726.292

[35] Bromley, D. W. (2013). Economic dimensions of community-based conservation. Natural Connections. https://doi.org/10.2307/jj.41379793.24

[36] Catalano, A. S., Lyons-White, J., Mills, M. M., & Knight, A. T. (2019). Learning from published project failures in conservation. Biological Conservation, 238, 108223. https://doi.org/10.1016/j.biocon.2019.108223

[37] Chopra, K., Cameron, T. C., Beecroft, R. C., Bristow, L., & Codling, E. A. (2025). Mapping activity of grazing cattle using commercial virtual fencing technology. Frontiers in Veterinary Science, 12. https://doi.org/10.3389/fvets.2025.1536977

[38] Curzon, H. F., & Kontoleon, A. (2016). From ignorance to evidence? the use of programme evaluation in conservation: Evidence from a delphi survey of conservation experts. Journal of Environmental Management, 180, 466-475. https://doi.org/10.1016/j.jenvman.2016.05.062

[39] Few, R. (2000). Conservation, participation, and power: Protected-area planning in the coastal zone of belize. Journal of Planning Education and Research, 19(4), 401-408. https://doi.org/10.1177/0739456x0001900409

[40] Galar, D., Sandborn, P., & Kumar, U. (2017). Maintenance budget versus global maintenance cost. Maintenance Costs and Life Cycle Cost Analysis. https://doi.org/10.1201/9781315154183-3

[41] Gravely, M., La Belle, B., & Balachandra, J. (2010). Independent assessment of the energy savings, environmental improvements and water conservation of emerging non-chemical water treatment technologies. ASME 2010 Citrus Engineering Conference. https://doi.org/10.1115/cec2010-5602

[42] Harrington, L. (2023). Nurses' overreliance on fallible technology. AACN Advanced Critical Care, 34(2), 84-87. https://doi.org/10.4037/aacnacc2023526

[43] Harrison, C., & Harris, L. D. (1985). The archipelago approach to conservation: Inspiring but unproven. Journal of Biogeography, 12(4), 381. https://doi.org/10.2307/2844869

[44] Hoag, D., Reuter, R., Mooney, D. F., Vitale, J. D., Ritten, J., DeLay, N. D., Evangelista, P. H., & Vorster, A. G. (2025). The economic fundamentals of virtual fencing compared to traditional fencing. Rangelands, 47, 92 - 101. https://doi.org/10.1016/j.rala.2024.05.006

[45] Hoffmeier-Karimi, R., & Schute, B. (2015). Assessing perceived and documented crop damage in a tanzanian village impacted by human-elephant conflict (HEC). Pachyderm, 56, 51-60. https://doi.org/10.69649/pachyderm.v56i.371

[46] Karthick, S., & Ramakrishnan, B. (2023). Is elephant proof trench an effective mitigating measure against human – elephant conflict?. Indian Forester, 149(10), 1010. https://doi.org/10.36808/if/2023/v149i10/157840

[47] Littin, K. (2010). Animal welfare and pest control: Meeting both conservation and animal welfare goals. Animal Welfare, 19(2), 171-176. https://doi.org/10.1017/s0962728600001421

[48] Malvern Karidozo, F. V. O. (2015). Community based conflict mitigation trials: Results of field tests of chilli as an elephant deterrent. Journal of Biodiversity & Endangered Species, 3(1). https://doi.org/10.4172/2332-2543.1000144

[49] Mekonen, S. (2020). Coexistence between human and wildlife: The nature, causes and mitigations of human wildlife conflict around bale mountains national park, southeast ethiopia. BMC Ecology, 20(1). https://doi.org/10.1186/s12898-020-00319-1

[50] Merciai, S. (2019). An input-output model in a balanced multi-layer framework. Resources, Conservation and Recycling, 150, 104403. https://doi.org/10.1016/j.resconrec.2019.06.037

[51] Mokhtari, M. (2016). Introductory chapter: A general overview of tsunami and effectiveness of early warning system. Tsunami. https://doi.org/10.5772/65081

[52] Moore, D. E., & Doyle, C. E. (1986). Elephant training and ride operations, part i: Animal health, cost/benefit and philosophy. Elephant, 2(2), 19-31. https://doi.org/10.22237/elephant/1521731987

[53] Nicole, B. F. (2019). An assessment of the human-wildlife conflict across africa. Wildlife Population Monitoring. https://doi.org/10.5772/intechopen.82793

[54] R. Kideghesho, J., & A. Rija, A. (2019). Introductory chapter: Wildlife management - failures, successes, and prospects. Wildlife Management - Failures, Successes and Prospects. https://doi.org/10.5772/intechopen.79528

[55] Schmidt, M., Jaitner, T., Nolte, K., Rheinländer, C., Wille, S., & Wehn, N. (2014). A wearable inertial sensor unit for jump diagnosis in multiple athletes. Proceedings of the 2nd International Congress on Sports Sciences Research and Technology Support. https://doi.org/10.5220/0005145902160220

[56] Smit, C., & Ruifrok, J. L. (2011). From protégé to nurse plant: Establishment of thorny shrubs in grazed temperate woodlands. Journal of Vegetation Science, 22(3), 377-386. https://doi.org/10.1111/j.1654-1103.2011.01264.x

[57] Stern, M. J. (2017). Caveating behavior modification approaches to conservation. Conservation Letters, 10(2), 267-268. https://doi.org/10.1111/conl.12271

[58] Verdon, M., Hunt, I., Forster, L., & Rawnsley, R. (2026). The welfare of dairy cows managed with halter virtual fencing and herding technology compared with those managed with electric fencing and stockperson herding. animal, 20(5), 101817. https://doi.org/10.1016/j.animal.2026.101817

[59] (2003). Reviving industrial buildings: An overview of conservation and commercial interests. Industrial Buildings. https://doi.org/10.4324/9780203362471-9

[60] (2013). Conservation in the general economic process. Petroleum Conservation in the United States. https://doi.org/10.4324/9781315064093-16

[61] (2014). Job creation and local economic development. OECD. https://doi.org/10.1787/9789264215009-en

[62] (2019). Technology innovation for green growth and sustainable resource management. Resources, Conservation and Recycling, 141, 501. https://doi.org/10.1016/j.resconrec.2018.05.003

[63] (2020). Peer review #1 of "social influence on the effectiveness of virtual fencing in sheep (v0.2)". https://doi.org/10.7287/peerj.10066v0.2/reviews/1

[64] (2022). Permanent high-tensile wire electric fence, installation and maintenance in mountainous region of southwest china. Journal of Electrotechnology, Electrical Engineering and Management, 5(1). https://doi.org/10.23977/jeeem.2022.050109

[65] Carter, E. (2019). WSAVA animal welfare guidelines. Animal Welfare, 28(1), 118-118. https://doi.org/10.1017/s0962728600010770

[66] Clemons, E., & Hitt, L. (2004). Poaching and the misappropriation of information: Transaction risks of information exchange. 37th Annual Hawaii International Conference on System Sciences, 2004. Proceedings of the. https://doi.org/10.1109/hicss.2004.1265504

[67] George, D., Dr.T.Baskar, & Dr.M.M.Karthikeyan. (2026). India's M.A.N.A.V vision: Redefining global AI governance through Human-Centric principles and strategic sovereignty. Zenodo (CERN European Organization for Nuclear Research). https://doi.org/10.5281/zenodo.18730381

[68] Daniel, J. C. (1980). The status of the asian elephant in india. Elephant, 1(4), 16-28. https://doi.org/10.22237/elephant/1521731714

[69] George, D. (2026). Architectural Convergence in Security Operations: a technical framework for AI-Augmented Threat Detection, Automated response, and Organizational cyber resilience. Zenodo (CERN European Organization for Nuclear Research). https://doi.org/10.5281/zenodo.19986642

[70] Jadhav, S., & Barua, M. (2012). The elephant vanishes: Impact of human–elephant conflict on people's wellbeing. Health & Place, 18(6), 1356-1365. https://doi.org/10.1016/j.healthplace.2012.06.019

[71] Publication, A. R. R. (2026). Securing Tomorrow: How 6G networks and AI are reshaping the cybersecurity landscape. Zenodo (CERN European Organization for Nuclear Research). https://doi.org/10.5281/zenodo.18299699

[72] George, D., & George, A. (2025). The AI Job Revolution - How emerging roles are reshaping the future of work and creating new career pathways. Zenodo (CERN European Organization for Nuclear Research). https://doi.org/10.5281/zenodo.17009242

[73] Singh, K. (2026, June 25). Railway safety boost: AI system and metal fencing to protect elephants in Chakradharpur division. HelloRail. https://hellorail.in/news/railway-ai-system-elephant-protection-chakradharpur/

[74] George, D., Dr.T.Baskar, & Siranchuk, D. (2025). Examining university obsolescence claims in the conversational AI era. Zenodo (CERN European Organization for Nuclear Research). https://doi.org/10.5281/zenodo.17715188

[75] Locke, P. (2016). Conflict, coexistence, and the challenge of rethinking human–elephant relations. Conflict, Negotiation, and Coexistence. https://doi.org/10.1093/acprof:oso/9780199467228.003.0001

[76] Sukumar, R. (2003). Mothers, children, and aunts the social life of elephant families. The Living Elephants. https://doi.org/10.1093/oso/9780195107784.003.0004

[77] (2008). Rollin's theory of animal welfare and its ethical implications. Animal Welfare. https://doi.org/10.1007/978-1-4020-8619-9_9

[78] (2016). Privacy conservation and public inspection for secure cloud storage. International Journal of Science and Research (IJSR), 5(4), 116-119. https://doi.org/10.21275/v5i4.25031610

[79] (2020). Conservation data management. Plant Genetic Conservation. https://doi.org/10.1017/9781139024297.020

[80] Eisenberg, J. F. (1980). Ecology and behavior of the asian elephant. Elephant, 1(5), 36-56. https://doi.org/10.22237/elephant/1521731835

[81] Galanti, V., Rossi, R., Tosi, G., Foley, C., & Foley, L. (2000). Elephant capture, collaring and radio-tracking in tarangire national park, tanzania. Pachyderm, 28, 58-59. https://doi.org/10.69649/pachyderm.v28i1.997

[82] Musinska, J., Skalickova, S., Nevrkla, P., Kopec, T., & Horky, P. (2025). Unlocking potential, facing challenges: A review evaluating virtual fencing for sustainable cattle management. Livestock Science, 295, 105693. https://doi.org/10.1016/j.livsci.2025.105693

[83] Ta, T., Baras, J. S., & Zhu, C. (2014). Improving smartphone battery life utilizing device-to-device cooperative relays underlaying LTE networks. 2014 IEEE International Conference on Communications (ICC). https://doi.org/10.1109/icc.2014.6884157

[84] Talukdar, N. R., Barbhuiya, R. A., & Choudhury, P. (2017). Population structure of wild asiatic elephant in patharia hills reserve forest, karimganj, india: A plea for conservation. Journal of Entomology and Zoology Studies, 5(2t), 1493-1498. https://doi.org/10.22271/j.ento.v5.i2t.06

[85] Tiller, B., Zufelt, R., Turner, S., Cadwell, L., Bender, L., & Turner, G. (2000). Population characteristics and seasonal movement patterns of the rattlesnake hills elk herd - status report 2000. https://doi.org/10.2172/765033

[86] Wu, Q., Dai, Y., & Sun, Q. (2024). Human–wildlife conflict patterns and hotspot prediction in the southern foothills of the daba mountains, china. Frontiers in Ecology and Evolution. https://doi.org/10.3389/fevo.2024.1435811

[87] (2021). Man elephant conflicts. AkiNik Publications. https://doi.org/10.22271/ed.book.1241

[88] Anand, B. A., Manoj, R., Mokshitha, V. S., & Raj, B. A. S. (2026). Artificial intelligence-based geo-fencing systems to avoid animal invasion in the agricultural fields. Archives of Current Research International, 26(6), 73-81. https://doi.org/10.9734/acri/2026/v26i61938

[89] Black, S. (2024). Avoiding pitfalls in conservation leadership. Conservation Leadership. https://doi.org/10.4324/9781003041917-3

[90] Child, B. (2019). Economic principles for wildlife governance. Sustainable Governance of Wildlife and Community-Based Natural Resource Management. https://doi.org/10.4324/9781315211152-6

[91] Dharmarajan, G. (2026). Effects of bias when using 'black box' models: Re-evaluating the evidence for the use of name-like calls by elephants. Animal Behaviour, 235, 123547. https://doi.org/10.1016/j.anbehav.2026.123547

[92] Hickey, I., Rose, P., & Rowden, L. (2022). The behavioural biology of ungulates and elephants. The Behavioural Biology of Zoo Animals. https://doi.org/10.1201/9781003208471-9

[93] Mel, S. J. C. D., Seneweera, S., Mel, R. K. D., Medawala, M., Abeysinghe, N., Dangolla, A., Weerakoon, D., Maraseni, T., & Allen, B. (2022). Virtual fencing of captive asian elephants fitted with an aversive geofencing device to manage their movement. Applied Animal Behaviour Science. https://doi.org/10.1016/j.applanim.2022.105822

[94] Rees, P. A. (2021). Elephant social structure, behaviour and complexity. Elephants Under Human Care. https://doi.org/10.1016/b978-0-12-816208-8.00003-8

[95] Shrestha, A., Pradhan, N. M., Shrestha, B., Pangeni, M., & Pandey, B. P. (2024). Human casualties from human-elephant conflict around koshi tappu wildlife reserve, nepal. Gajah, 3-12. https://doi.org/10.2305/cjsl2627

[96] Waithaka, J. (1998). Trends of elephant poaching in kenya: The elephant mortality database.. Pachyderm, 25, 40-41. https://doi.org/10.69649/pachyderm.v25i1.919

[97] Zerbe, R. O. (2013). Ethical benefit–cost analysis as art and science: Ten rules for benefit–cost analysis. Principles and Standards for Benefit–Cost Analysis. https://doi.org/10.4337/9781781953433.00014