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Integrating Geospatial and Real Time Technologies for Risk zone monitoring in Periyar Tiger Reserve, India.

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Abstract: There are numerous monitoring technologies available today, owing to the rapid advancements in technology and the increasing demand for safety and security in forests. Real-time monitoring with AI cameras, which are commonly utilized for creating and updating real-time features through surveillance, stands out as one of the most effective monitoring solutions. The objective of this current research is to monitor various risk zones within the Periyar Tiger Reserve by integrating real-time AI camera with geographic data. AI cameras were strategically placed using spatial analysis techniques. Using Geographic Information System (GIS) technology, the system enables spatiotemporal management of multiple cameras and their data. The GIS map displays the spatial distribution and monitoring ranges of AI cameras, along with camera layout densities and related data stored in a geospatial database. Integrating historical risk areas with camera locations further improves the system's ability to create accurate topological links between cameras and key points of interest. The results revealed that only 13% of the risk zone was observable from the nine available Real Time Monitoring towers. However, with the addition of 51 more towers, the visibility of the risk zone would increase to 40%. The remaining 15% of the risk zones were not visible through the existing infrastructure. To enhance coverage while minimizing environmental impact, we propose increasing the height of monitoring towers to the maximum permissible limit and utilizing advanced zoom cameras. While the current 6-meter towers are effective, further increasing their height can significantly boost the network's efficiency, ensuring that all critical areas are adequately covered and monitored. This approach will ultimately lead to better management and mitigation of risks in the designated zones.

Keywords: Visibility analysis, Real time Monitoring Network, Risk zones

1. Introduction

In recent years, advancements in artificial intelligence (AI) have transformed numerous industries, including forest management. One of the most innovative applications of AI in this field is the use of AI cameras for risk management in forests. These AI-powered cameras leverage machine learning algorithms to monitor and analyse forest environments continuously. AI cameras play a crucial role in enhancing forest management strategies by detecting and alerting authorities to potential risks such as forest fires, illegal activities, and environmental disturbances. This introduction will explore the significance of AI cameras in forest risk management, highlighting their capabilities, benefits, and potential impact on preserving and protecting forest ecosystems. Monitoring risk zones in forests using AI cameras is a cutting-edge approach to forest management. These AI cameras are equipped with sophisticated algorithms that can detect various risk factors such as potential fire hazards, unusual activities, or environmental changes indicative of heightened danger. By deploying AI cameras strategically throughout forested areas, authorities can gather real-time data and promptly respond to emerging threats, thus enhancing overall forest protection and management efforts. Recent advancements in Geographic Information Systems (GIS) and computer technology have enabled the use of GIS-based decision support systems in all phases of forest fire management, including fire prevention, firefighting, and post-fire recovery efforts (Küçük and Bilgili 2006; Akay et al. 2012).

In recent years, Geographic Information System (GIS) techniques have been applied to monitor forest fires, create fire risk maps, and develop firefighting strategies (Vipin 2012; Sivrikaya et al. 2014). View shed analysis, using profile extraction methods in GIS, has been effectively used to determine areas visible from specific locations (Singh et al. 2014). Akbulak and Özdemir (2008) applied visibility analysis to assess forest lands visible and not visible from fire lookout towers in the Gallipoli Peninsula, Turkey, noting that much of the coniferous forest was not visible from the existing towers. Similarly, GIS and remote sensing techniques have been used to evaluate the placement of lookout towers in relation to fire risk zones (Korale et al. 2009).

Pompa-García et al. (2010) recommended combining visibility analysis with a digital elevation model (DEM) and vegetation cover maps, finding that only 43% of forest lands were visible from the towers, leaving over half unmonitored. In another study, GIS was used to assess the visibility of fire lookout towers in northern Turkey, a region with a Mediterranean climate (Kucuk et al. 2017). The role of local residents using inner forest roads was highlighted as an essential part of the fire monitoring system. (Coban et. al., 2020) suggested integrating GIS-based methods, such as digital camera systems and remote sensing, alongside traditional lookout towers for more cost-effective and efficient fire surveillance planning.

In this study, GIS-based visibility analysis was employed to identify visible and non-visible risk zones within the Periyar Tiger Reserve, utilizing data from a real-time monitoring tower situated in the study area. Subsequently, the effectiveness of a new tower was assessed through visibility analysis, and the connectivity between towers was examined using Arc GIS 10.4.

2.Data and Methodology

2.1 Study Area

This study was carried out in and around Periyar Tiger Reserve, located in Idukki district of Kerala, India. It is spread over an area of 925 sq km, of which 881 sq km is the core area, and the rest is buffer. Periyar Tiger Reserve spread over the Agasthiyamala Landscape. This Tiger Reserve has the greatest number of tigers in the Kerala counted to 30 tigers (Figure1.).

2.2 Materials

2.2.1 Digital Elevation model

Digital Elevation Model (DEM) data is crucial for visibility analysis in monitoring fire-prone areas. DEM provides detailed information about the terrain, including elevation, slopes, and surface characteristics, which are essential for determining the line of sight from lookout towers and other observation points. By utilizing DEM data, forest management can accurately assess the visibility coverage of existing lookout towers and identify blind spots that might be vulnerable to undetected fires. This information helps in optimizing the placement of additional observation points or towers to ensure comprehensive monitoring coverage. Furthermore, DEM data enables the integration of Geographic Information Systems (GIS) and remote sensing technologies, improving the accuracy of fire detection and response planning. By combining DEM data with GIS, authorities can simulate various scenarios, predict fire behaviour, and plan optimal routes for fire suppression teams. This integration is not only economically and operationally beneficial but also significantly improves the technical effectiveness of fire monitoring systems. In this study, ALOS PALSAR DEM was downloaded from Alaska Satellite Facility- Vertex portal with 12.5 m Resolution (Figure 2).

2.2.2 Risk hotspot map

Veeramani S et al. (2024) created risk maps for multiple hazards using the Max Ent (Maximum Entropy) machine learning technique (Figure 3.), which utilized 13 geo-environmental parameters as predictors. The accuracy of these models was assessed using receiver operating characteristic (ROC) curves and the area under the ROC curve (AUC). Key determinants for each risk were identified: elevation and distance from streams for flooding, soil and topographic roughness index for landslides, proximity to roads and livestock presence for human-wildlife conflict, and annual mean temperature for forest fires. An integrated multi-hazard map indicated that 55% of the area is at risk, with specific proportions for landslides (31%), human-wildlife conflict (9%), floods (5%), and fires (10%).

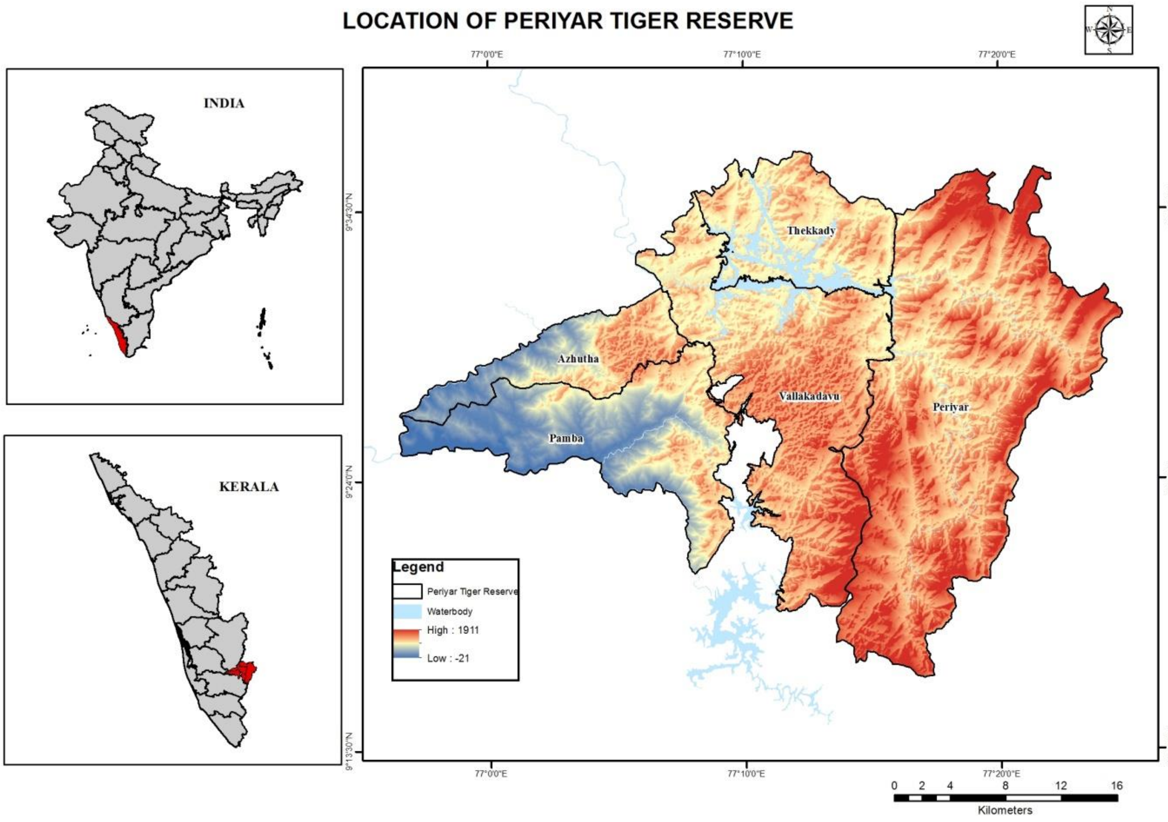

Figure 1. Study Area map

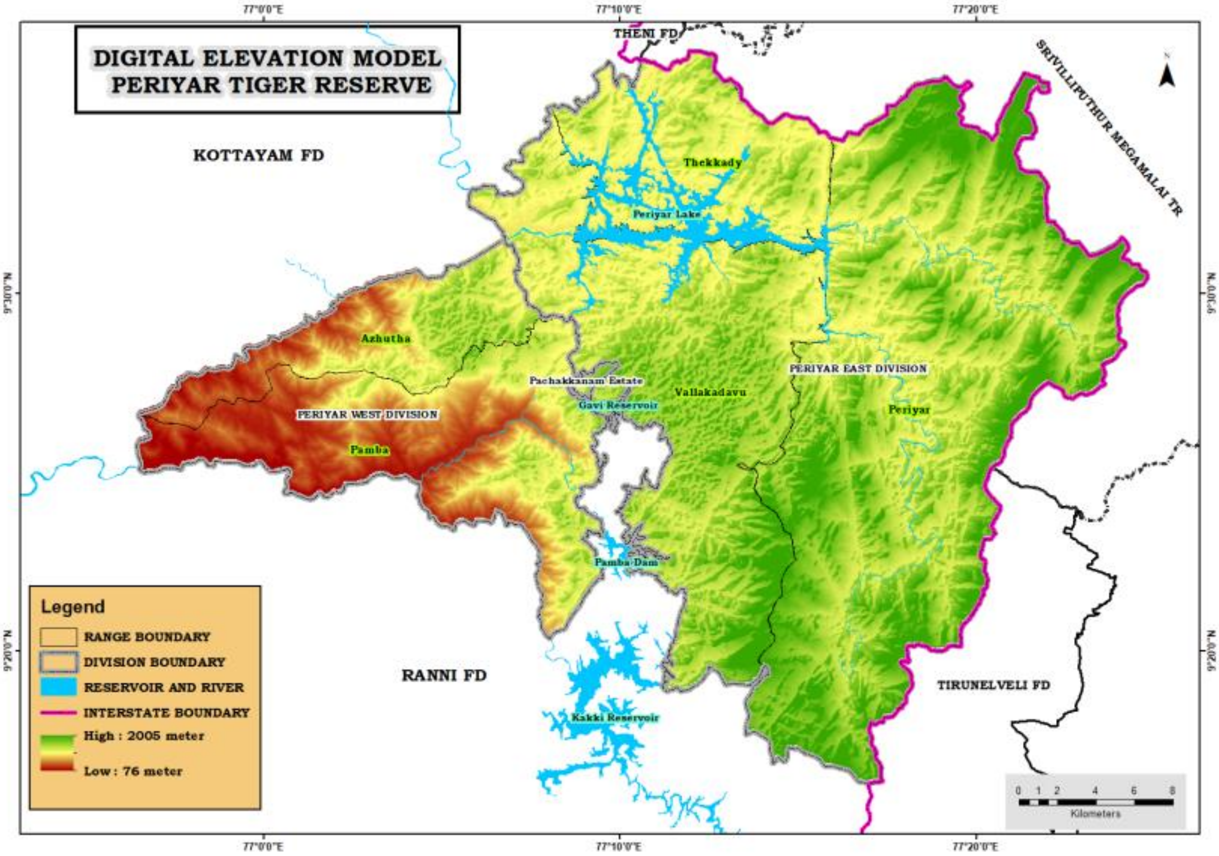

Figure 2. Digital Elevation Model

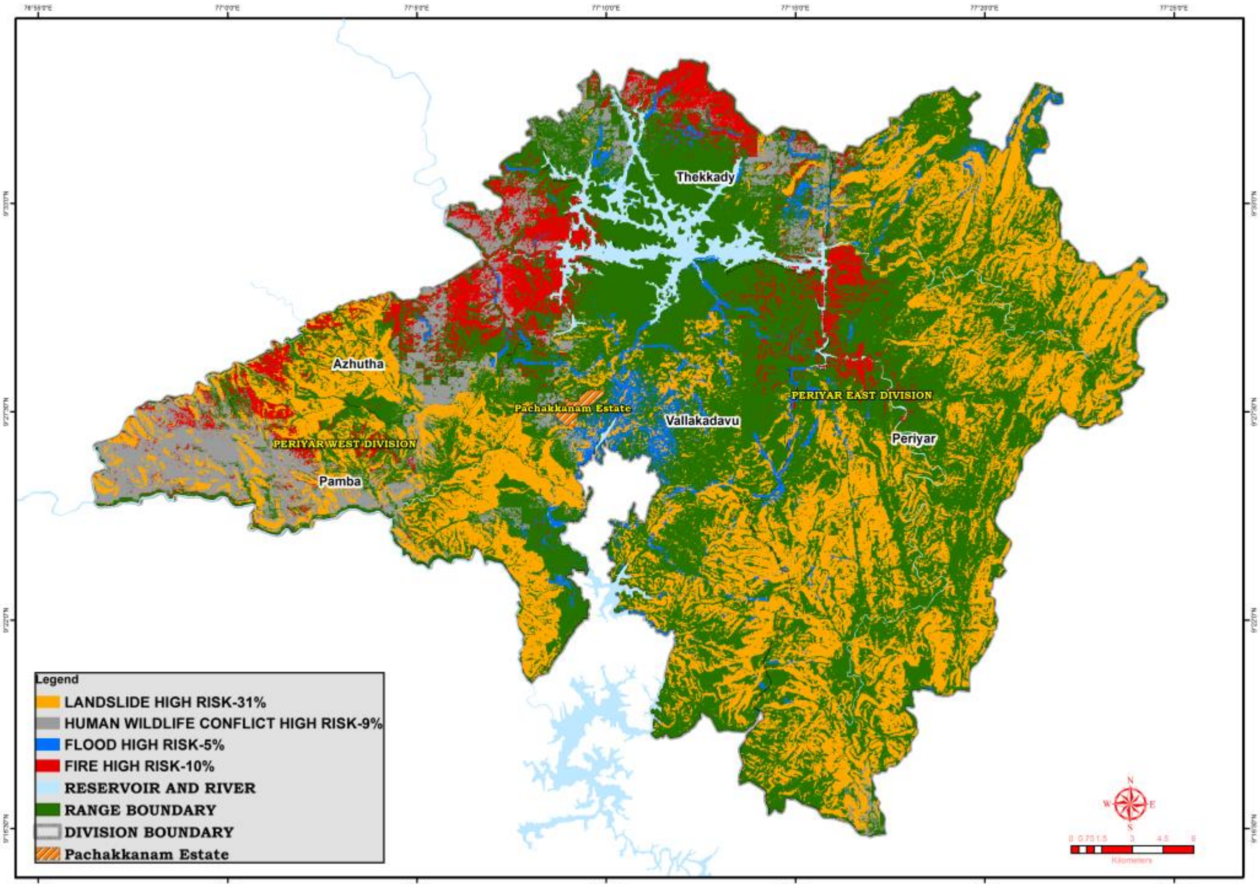

Figure 3. Risk Hotspots map

2.2.3 Real Time monitoring Technologies

Real-Time Monitoring (RTM) will be a technology that uses microwaves and a line-of-sight strategy. RTM will be used to monitor wildlife in prime habitats and will also serve as a protection method for vulnerable points in PTR. The cameras will have a range of a 3 km radius and PTZ 360° rotation, facilitating 24x7 monitoring of the habitat and wildlife. RTM will be installed in Phase I at Mangaladevi and Poovarasu (Vayal). A dish transmitting internet behind the Periyar Tiger Reserve Division office will transmit microwaves to Mangaladevi through line-of-sight technology. The Rajiv Gandhi office will also transmit microwaves to Mangaladevi using the same technology. The intranet from Mangaladevi will then be transmitted to Poovarasu (Vayal) using the same method. Here, the movement of wildlife will be monitored 24x7 from the control center at Thekkady. Once the tower is installed, the activities of wildlife visiting the Vayal will be recorded, allowing for important behavioral studies to be conducted using these RTM video recordings in the future, in addition to monitoring risk zones. RTM will also be implemented in Manamutty, a grassland near Vallakadavu. Phase II will aim at covering vulnerable points at Kathiramudy through Palkachi, Mullakudy, Kumarikulam, and Thannikudy.Phase II will be highly useful in monitoring the interstate movement along the PTR border, thereby strengthening protection along with wildlife monitoring. RTM will also serve as a fire management tool; since fire incidents mostly occur in grasslands, these real-time cameras will help in detecting risks immediately through remote monitoring and will aid in rapid action by the frontline staff to prevent the spread to other areas. In this study, the possible view shed of risk zones will be extracted using GIS analysis, providing important input for the upgrading and extension of the RTM network to the next level.

For the installation of one tower with an AI camera, various essential components are required. These include a PC with minimum specifications of an i3 12th Gen processor, 8GB DDR4 RAM, and a 512 SSD; a 1 KV inverter with MPPT charge controller; C10 200 AH AGM Tubular Solar Batteries; Monoperk Half cut Solar Panels (550 W); and MikroTik LHG XL HP5 Radio Modems. The surveillance system will utilize Bullet IP Cameras (4 MP), and network security will be ensured by a firewall (CYBERROM or FORTINET). Additionally, the setup includes a WiFi controller, access points with licenses, and other electrical and electronic accessories. The tower itself will consist of a waterproof battery and network equipment box, solar panel stands, radio modem stands, and a height extendable pipe. An allowance for unforeseen items is also included. The total cost for this comprehensive installation is Rs. 1,093,422.62/-. Real-time monitoring in forest areas using cameras is essential for various purposes, including wildlife conservation, illegal activity detection (such as poaching and logging), fire detection, and ecosystem research. Microwaves are commonly used for point-to-point communication due to their small wavelength, which allows for the use of compact antennas to direct signals in narrow beams aimed at the receiving antenna. Another benefit is the high frequency of microwaves, providing them with a large information-carrying capacity, offering 30 times more bandwidth than the entire radio spectrum below them. However, a limitation is that microwaves rely on line-of-sight transmission and cannot bend around obstacles like hills or mountains, unlike lower frequency radio waves. Directional microwave dish antennas (with Internet Protocol) were used to establish communication between two points. The communication was conducted using 5.8 GHz, 2.4 GHz, or 900 MHz frequencies. Higher the frequency, lower will be the antenna size but the penetration will be less. There are a wide variety of brands available in the market viz., Cambium of Motorola, Ubiquitii, etc. Initially, the RTM was deployed in nine locations, and subsequently, the connection has been extended to other camp shed locations. This analysis has provided insights into both visible and non-visible areas from the existing locations. It indicates that the existing RTM network locations serve as a suitable platform for achieving extensive signal coverage within the study area.

2.2.4 System architecture

The study developed an integrated system with a three-layer architecture: data, processing, and presentation layers (Figure 4). The data layer consists of geographic and camera attribute data, which are essential for camera positioning, density statistics, and spatial analysis. The processing layer integrates GIS and video surveillance for camera mapping, density calculations, spatial relations, and video analysis, including object detection, tracking, and re-identification. The presentation layer serves as the user interface, displaying maps, markers, and videos, while managing requests and delivering responses.

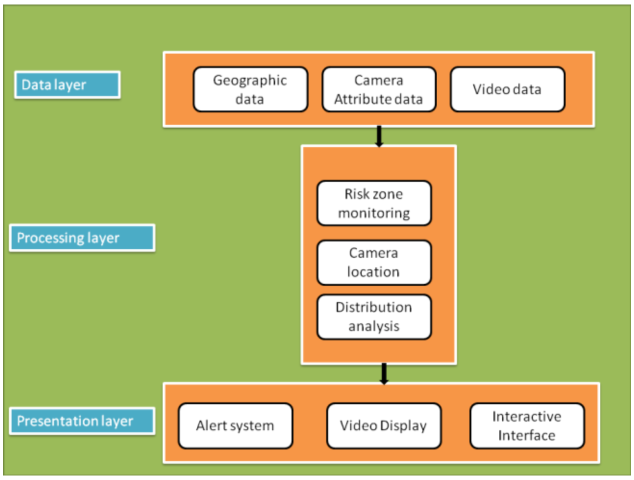

Figure 4. System Architecture

Table 1. The field data of RTM tower Layer

SL.No	Name	Tower height (m)	Smoke Height (m)	Horizontal angle (Degree)	Vertical angle (Degree)	Elevation (m)
1	Rajiv Gandhi Office Complex	6	100	360	90	907
2	Mangaladevi Campshed	6	100	360	90	1331
3	Palkachi	6	100	360	90	1202
4	Kumarikulam Campshed	6	100	360	90	1270
5	Kathiranmudi	6	100	360	90	1363
6	Paloda Vayal	6	100	360	90	917
7	Thannikkudy	6	100	360	90	899
8	Mullakkudy SHQ	6	100	360	90	891
9	Manammutty Mala	6	100	360	90	1072

2.2.5 Visibility analysis

Visibility analysis was conducted using the "Observer Points" feature in ArcGIS 10.4.1. Data fields necessary for this analysis were added to the attribute table of the data layer, indicating the locations of the existing RTM tower. In this study, a viewing angle of 360 degrees was set to cover the entire working area from the tower. The smoke visibility height was established at 100 meters to ensure detection of both flames and smoke during a fire. Vertical viewing angles were set to +90 degrees and -90 degrees. Visibility distances and additional information about the RTM towers are presented in Table 1. In the second stage, the visible areas from the potential RTM tower in the study area were identified. Subsequently, both visible and non-visible areas from the lookout towers were marked for the risk zones in Periyar Tiger Reserve. A map of risk hotspot areas was then utilized to assess the visibility of vulnerable regions.

3. Results and Discussion

Risk zones (forest fire, flood, landslide, and human-wildlife conflict) in the study area were identified using the MAXENT environment (Phillips et al., 2006; Elith et al., 2011). Initially, all feature maps were converted from the GCS-WGS-1984 geographic coordinate system to the WGS-1984-UTM-Zone-43N plane coordinate system, suitable for the research area. Polyline vector maps of power lines, water bodies, and point vector maps of human settlements were used to create Euclidean distance raster maps, measuring distances from seismic events to these features. The DEM facilitated the production of topographic feature maps, including elevation, slope, aspect, accumulation, TRI, plan curvature, profile curvature, TPI, TWI, SPI, and LS factor. Additionally, averaged NDVI and forest cover raster maps were utilized to train the algorithm. A CSV file was generated from the presence-only dataset of forest hazard events, which served as input for generating multi-hazard maps (Veeramani et al., 2024). The analysis revealed that 55% of the area is at risk, with landslides comprising 31%, human-wildlife conflict 9%, floods 5%, and fires 10% (Table 2). A data layer illustrating the risk zone areas was subsequently produced, as shown in figure 5.

Table 2. The areal distribution of Risk Types

SL.No	Name	Area (%)
1	Forest Fire	10
2	Flood	5
3	Landslide	31
4	Human wildlife conflict	9
5	Zero Risk areas	45
	Total	100

According to the results of the visibility analysis, the areas observed by the existing RTM tower is shown in Figure 6. It was found that 13 % of the risk zone was visible from the existing tower.

Table 3. The Risk zone from the RTM tower (55 %)

Number of observing towers	Towers	Area (%)
9	Existing	13
51	New	38
60	Both	40
-	Not visible	15
	Total	55

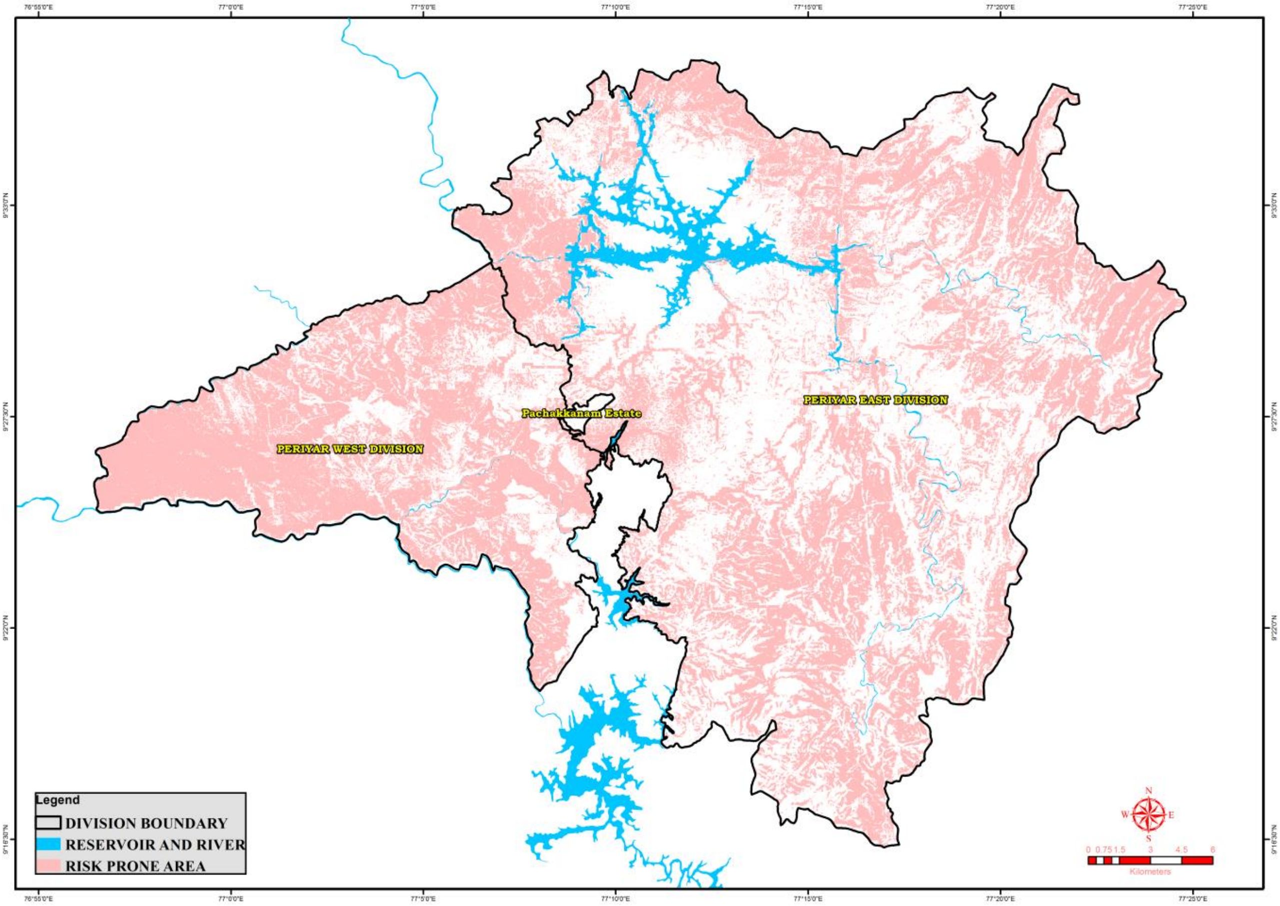

Figure 5. Risk zones in the Periyar Tiger Reserve.

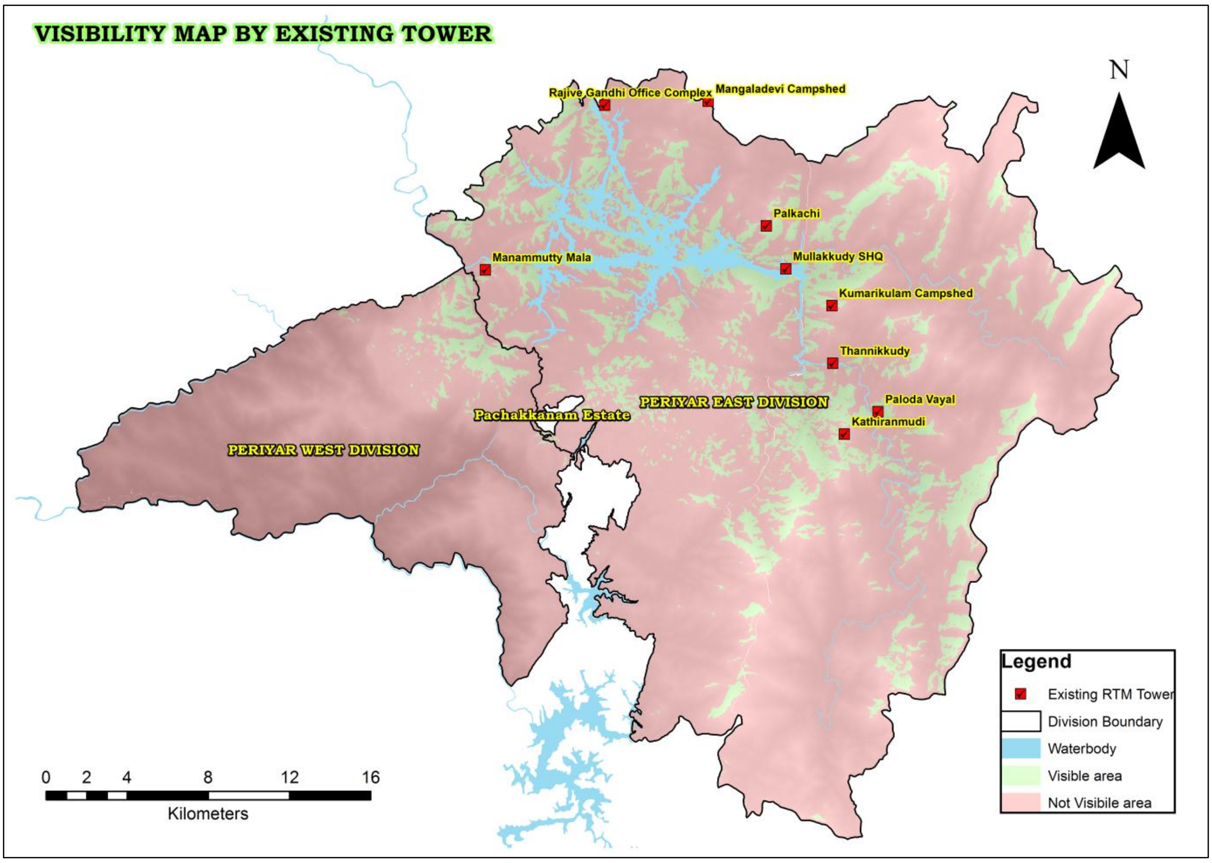

Figure 6. Area observed by Existing Tower.

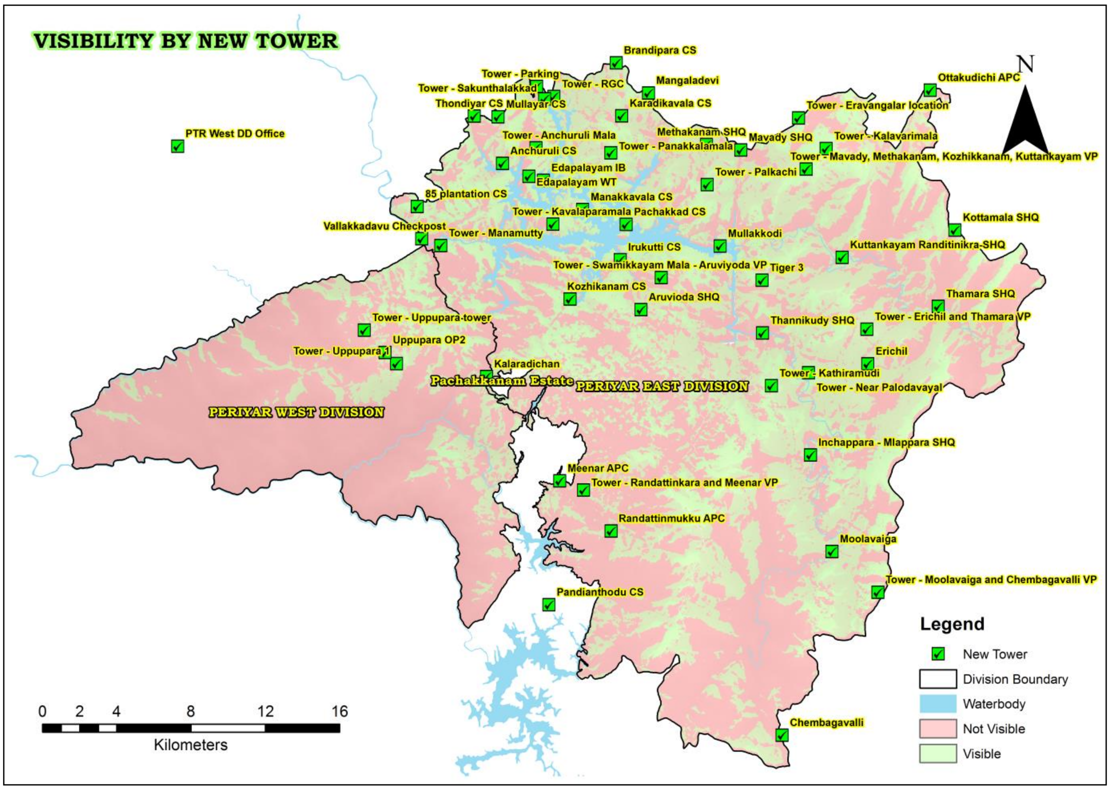

Figure 7. Visible areas from New Tower

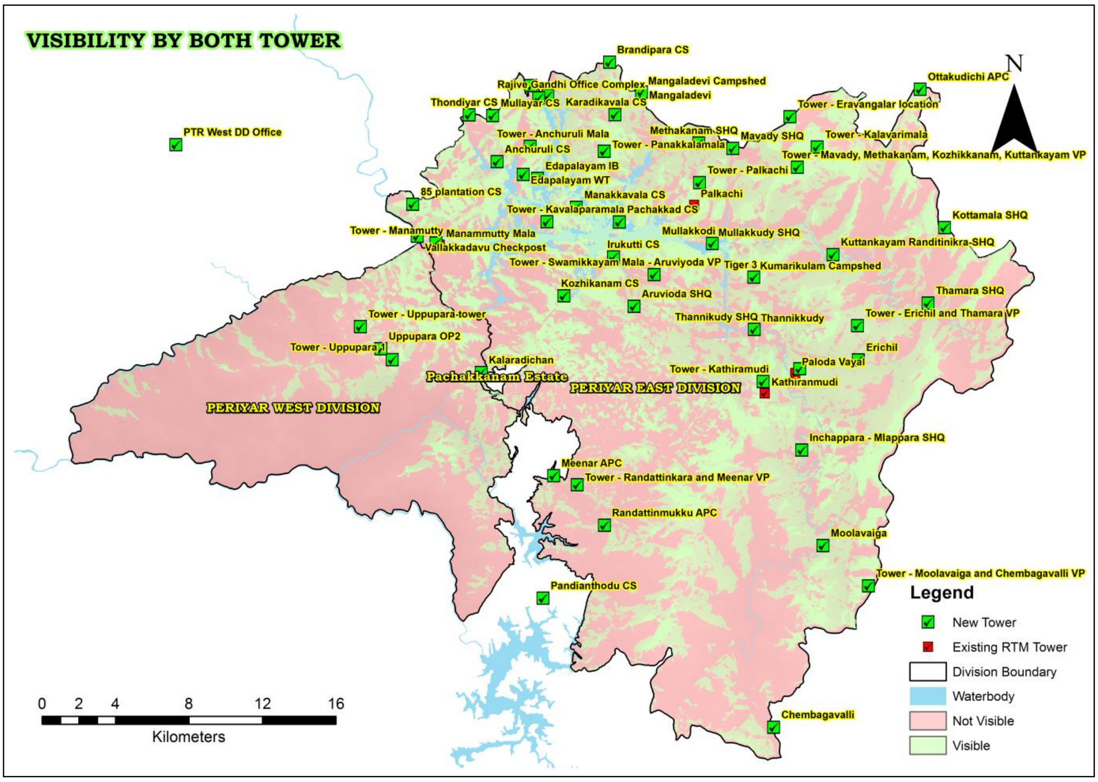

Figure 8. Visible areas from both towers

When considering the potential new RTM tower in the study area, the visible areas from both existing and new tower increased to 40 %. Thus, installing new RTM tower provided additional 27 % of visible area in the study area (Figure 7.) Therefore, 27 % of additional visible forest area was provided after installing the new tower. Thus, the visible area from both towers were given in figure 8. Indivisibility analysis has also been conducted, and the connectivity map is provided in figure 9.

The study indicates that signal reception is lacking in most locations in Periyar West division. The analysis reveals that internet wireless signal coverage in the area is constrained by geographic features such as rocks, canopy, and terrain. However, comprehensive signal coverage can be achieved at high peaks and ridges, as well as by elevating the height of the wireless service transmitting tower to maximum permissible limit. To address these challenges, a dedicated networking plan will be initiated for non-visible areas. Additionally, line-of-sight ground surveys will be conducted in visible areas to establish connections effectively. This approach aims to enhance the overall communication infrastructure and ensure reliable internet connectivity throughout the region.

Research Results on Connectivity and Coverage of Towers in Risk Zones

The analysis of tower coverage in risk zones has yielded promising results. A 6-meter tower has been found to be more than sufficient to cover approximately 60% of the designated risk zones. This tower height ensures a coverage radius of 14 kilometers and offers a comprehensive 360-degree view, facilitating extensive monitoring and connectivity.

Additionally, the research highlights the importance of various specific locations in enhancing connectivity:

1. **85 Plantation Campshed**: This location provides connectivity to 7 other strategic locations, forming a critical node in the network.

2. **Edapalayam IB**: This site is notably significant, offering connectivity to 9 different locations (Table 3). This makes it an essential hub for communication and monitoring within the network.

3. **Mangala Devi**: This location stands out by providing connectivity to 12 different locations. The extensive reach of Mangala Devi makes it a pivotal point in the connectivity network.

4. **Manamutty Tower**: This tower currently connects to 9 locations. Despite its already significant contribution, there is potential for further optimization.

5. **Uppupara Tower**: With connectivity to 11 locations, the Uppupara Tower plays a crucial role in the overall network.

The analysis suggests that increasing the height of the towers, especially at key locations like Manamutty and Uppupara, can further enhance coverage. By doing so, it will be possible to cover the remaining areas that are currently not within the network's reach. This strategy will not only ensure comprehensive coverage of the risk zones but also improve the robustness and reliability of the communication network.

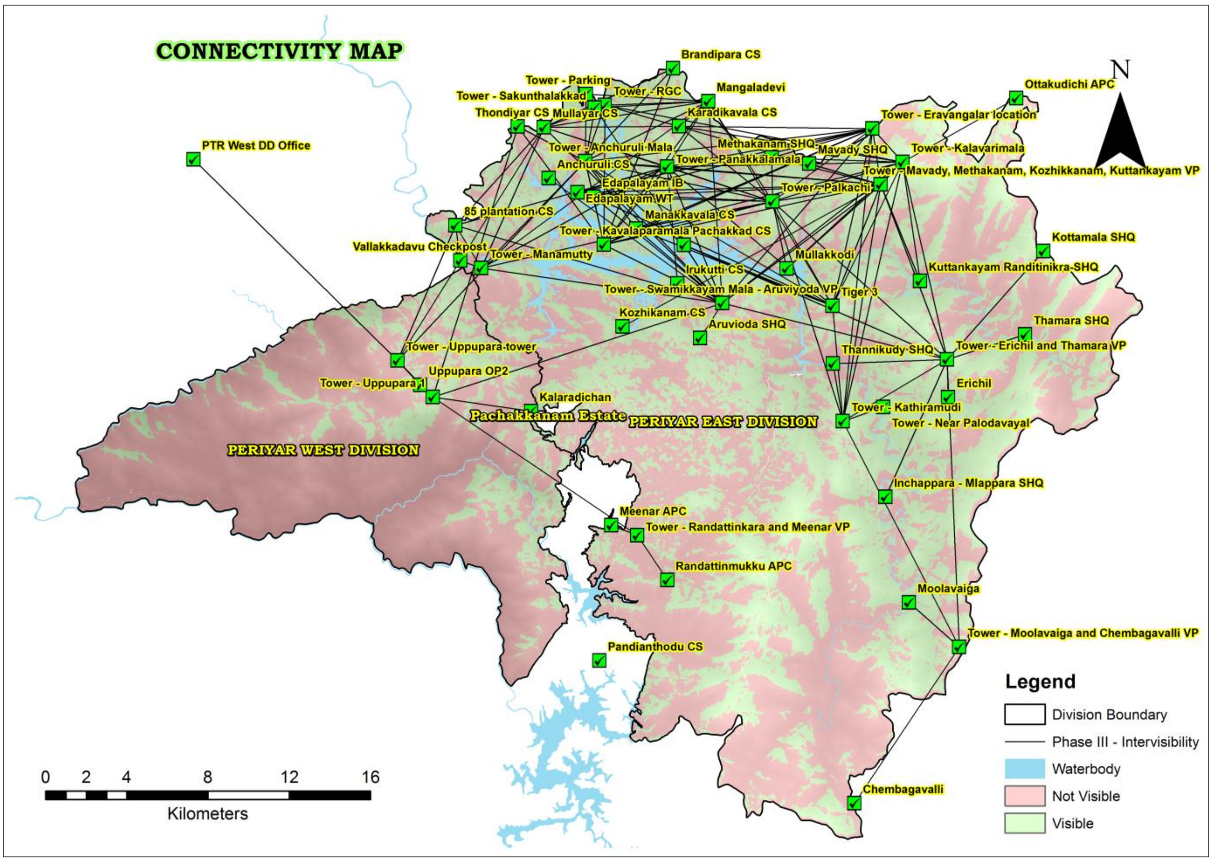

Figure 9. Connectivity map of New Towers

4. Conclusions

GIS-based visibility analysis was utilized to identify visible and non-visible risk zones from Real-Time Monitoring Towers. The visibility of nine camera towers was analysed in relation to the risk-prone areas of the Periyar Tiger Reserve, which contained nine watch towers. The visibility analysis aimed to identify the risks observable from each RTM tower, the risk areas visible from multiple towers, and the risk areas that are not detectable from any tower. The results revealed that only 13% of the risk zone was observable from the nine available RTM watch towers. However, with the addition of 51 more towers, the visibility of the risk zone would increase to 40%. The remaining 15% of the risk zones were not visible through the existing infrastructure. To enhance coverage while minimizing environmental impact, we propose increasing the height of monitoring towers to the maximum permissible limit and utilizing advanced zoom cameras. Based on these findings, it can be stated that the number of RTM towers in the area of study was insufficient, and their positions were appropriate, for efficiently monitoring possible forest risk zones. AI-based cameras are also quite useful for this type of risk management in forest areas. the study emphasizes the strategic importance of tower height and placement in maximizing coverage and connectivity. The current 6-meter towers are effective, but further increasing their height can significantly enhance the network's efficiency, ensuring that all critical areas are adequately covered and monitored. This approach will ultimately lead to better management and mitigation of risks in the designated zones.

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References

Akay A. E., G. M. Wing, F. Sivrikaya and D. Sakar (2012). A GIS based decision support system for determining the shortest and safest route to forest fires: a case study in Mediterranean Region of Turkey. Environmental Monitoring and Assessment, 184(3), 1391-1407.

Akbulak C. and M. Özdemir (2008). The Application of the Visibility Analysis for Fire Observation Towers in the Gelibolu Peninsula (NW Turkey) Using GIS. BALWOIS 2008, 27-31 May, Ohrid, Republic of Macedonia.

Coban O. and H. Bereket (2020). Visibility analysis of fire lookout towers protecting the Mediterranean Forest Ecosystems in Turkey. Sumarski List. 393-407.

Elith J., S. J. Phillips, T. Hastie, M. Dudík, Y. E. and C. J. Yates (2011). A statistical explanation of Maxent for ecologists. *Diversity and Distributions*, 17(1), 43-57.

Korale P., A. Pade, A. Varghese and A. Joshi (2009). Mapping of forest fire risk zones and identification of suitable sites for fire watch towers using remote sensing and GIS. ISRS Symposium on Advances in Geo-spatial technologies with special emphasis on sustainable rain fed Agriculture, 17-19 September, Nagpur, India.

Kucuk O. and E. Bilgili (2006). The conveyance of fire behaviour characteristics into practice by using geographical information systems (GIS): A case study in Kastamonu. Gazi University. (2), 262–273.

Kucuk O., O. Topaloglu, A. O. Altunel and M. Cetin (2017). Visibility analysis fire lookout towers in the Boyabat state forest enterprise in Turkey, Environmental Monitoring and Assessment, 189(2017):329

Phillips S. J., R. P. Anderson and R. E. Schapire (2006). Maximum entropy modeling of speciesgeographic distributions. *Ecological Modelling*, 190(3-4), 231-259.

Pompa-García M., R. Solís-Moreno, T. E. Rodríguez, A. Pinedo-Álvarez, D. Avila-Flores, C., Hernández-Díaz and E. Velasco-Bautista (2010). Viewshed analysis for improving the effectiveness of watchtowers, in the north of Mexico. Open Forest Science Journal, 3:17-22.

Singh Y., M. P. Sharma, S. D. Sharma, R. Prawasi, K. Yadav and R. S. Hooda (2014). Application of GIS technique to select suitable sites for erecting watch towers in forest areas of mountainous tract. Int. J. Computer Technology and Applications (2):462-468

Sivrikaya F., B. Saglam, A. E. Akay and N. Bozali (2014). Evaluation of forest fire risk with GIS. Polish Journal of Environmental Studies 23(1):17-194

Veeramani S., S. S. Patil and R. S. Suja Rose (2024). Prediction of risk zones and wildlife exposure assessment in Periyar Tiger Reserve using machine learning approach in Kerala, India. Indian Journal of Ecology, 51(3) :500-510.

Vipin V. (2012). Image processing-based forest fire detection. Emerging Technology and Advanced Engineering 2(2):87–95