ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XI November 2025

Promoting Hiking Tourism through an Offline Mode Mobile Application Case Study: Horton Plains National Park, Sri Lanka

JLS Jayarathna, *PGRNI Pussella

Department of Remote Sensing and GIS, Faculty of Geomatics, Sabaragamuwa University of Sri Lanka, PO Box 02, Belihuloya, Sri Lanka

***Correspondence Author**

DOI: https://dx.doi.org/10.51244/IJRSI.2025.12110202

Received: 04 December 2025; Accepted: 12 December 2025; Published: 29 December 2025

ABSTRACT

Horton Plains National Park of Sri Lanka nestled in the central mountain range, holds immense potential for hiking tourism. However, the absence of a strategic approach to identifying new routes and the lack of an offline mapping application has hindered optimal exploration of the region's scenic terrains. This research leverages Geographic Information System (GIS) technology to identify safe and attractive hiking routes within Horton Plains National Park. The study encompasses comprehensive data collection, manual route design, and network analysis to unveil new trails. A user-friendly mobile application integrating offline maps was developed in the study in order to provide accessible and detailed route information to the hikers. The approach emphasizes the sustainable development of tourism and the economic growth of local communities. The study reveals that there is a need for diverse hiking options and enhancing the tourism experience. This research contributes to the promotion of hiking tourism in Sri Lanka, positioning Horton Plains as a premier destination for nature enthusiasts. Through a combination of GIS technology, data analysis, and mobile application development, this study offers a holistic approach to enhancing the hiking experience while fostering economic opportunities for local communities. The findings underscore the importance of strategic planning and technological innovation in sustainable tourism development, showcasing Horton Plains National Park as a unique and compelling destination for outdoor enthusiasts and nature lovers alike.

INTRODUCTION

Tourism, particularly nature-based tourism, has emerged as a crucial and economically significant in worldwide (Sumanapala and Wolf, 2023). Specially in protected areas and other natural destinations where nature is a crucial tourism attraction, tourists participate in various nature-based activities (Sumanapala and Wolf, 2023). In Sri Lanka, with its rich biodiversity and captivating mountain ranges, hiking tourism holds immense potential for attracting adventurous travelers seeking immersive experiences. However, the absence of a strategic approach to identifying new hiking routes and the lack of an offline mapping application have hindered the optimal exploration of the country's scenic terrains. This research aims to address these challenges by utilizing Geographic Information Systems (GIS) technology to identify safe and attractive hiking routes in Horton Plains National Park, Sri Lanka, and subsequently developing a user-friendly mobile application to facilitate hikers' navigation.

Finding a safe and comfortable route to reach the camping site or the mountain peak has been an untouched research area in Sri Lanka. It is necessary to have an offline mapping strategy in order to locate the desired path because signal strength of mobile phones is weak in mountainous locations. The usage of Global Positioning System (GPS) technology allows users to track their current location. These capabilities in a smartphone app could entice hikers from all over the world to Sri Lanka.

GIS is a system with truly immersive capability for navigating and understanding the complex and dynamic terrain-based databases (Koller et al., 1995). Application of GIS technology to design hiking routes is advantageous. It would assist the forest authorities in locating and suggesting fresh routes through the

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protected regions while also assisting in site protection. This strategy encourages the development of new hiking areas while easing congestion in popular tourist sites (Vías et al., 2018). Identification of possible and safe routes to mountain tops is essential for hiking related tourism activities generally. A mobile application consisted with an offline map and paths would reduce the straggling in the forests. Presently, there is no strategic approach in finding new hiking routes and an offline mapping application in Sri Lanka. This research aimed to introduce a mobile application with offline maps and hiking trails in the Horton Plains National Park.

The present study attempts to identify possible and secured track routes in the Horton plains national park of Sri Lanka. Though there are many scenic places suitable for hiking activities such as Kirigalpoththa and Agrabopath mountains etc in the study area, however, there is only one trail used by hikers. As a trending country with nature-based tourism potentials, it is encouraged to promote hiking tourism in Sri Lanka with the use of a smartphone application that includes new routes and stops with offline maps. As a supplementary benefit, the local communities closed to the hiking locations will get an economic growth as a result of the influx of local and international hiking tourists.

LITERATURE REVIEW

Hiking tourism is one of the most popular tourism related industries, since it is a fascinating outdoor sport for individuals or groups of different ages and socioeconomic levels (Calbimonte et al., 2020). Generally, the public participate in nature-based sport activities to release the stress and improve their mental health. Nordbo et al. (2014) defined hiking tourism as a vacation or holiday related outdoor activity that includes shorter or longer treks in natural and cultural environments, often in rural locations. In general, the pathways become busy at various times throughout the year producing saturation effects and unfavorable impressions to the visitors (Boller et al., 2010; Farias, 2011; Santana-Jimenez and Hernandez, 2011). Overcrowding impacts visitors and the environment (Vías et al., 2018).

Creating new hiking routes is critical for environmental sustainability and tourism management (Vías et al., 2018). Currently, GIS technology has emerged as a powerful tool for enhancing hiking tourism experiences. It allows to integrate various spatial data layers such as topography, locations of natural features, presence of infrastructure and details about restricted areas in order to analyze and visualize diverse these data to design efficient hiking trails that are safe, accessible, and minimize environmental impacts (Vías et al., 2018).

Turgut et al. (2021) introduced the Hiking Suitability Index (HSI) to evaluate hiking routes within forest areas in mountainous regions using a multi-criteria decision analysis taking length, altitude, slope and walking time as the main factors and aspect, access to clean water and landscape quality as sub factors. Vias et al. (2018) proposed an effective method for determining and evaluating hiking routes by analyzing physical obstacles, terrain suitability, management and network analysis in GIS utilizing the A* algorithm to find the starting point and end point in linking routes. Vias et al. (2018) used the criteria such as start and end locations of the path the appropriateness of the segments that make the path, the circularity, the availability of the path for public use and animals to evaluate the appropriateness of the routes.

In addition, Vias et al. (2018) determined the feasibility of the route using the difficulty level of the route and time taken calculated using the length and overall height gain. According to Bohannon & Andrews (2011), A hiker's average speed is between 2 and 6 km/h.

Longley et al. (2015) attempted to design a hiking route network considering connectivity, loop creation and access to key points of interest as main factors and maximum trail length and maximum elevation gain as guiding factors. Generally, network analysis involves modeling the trail network as a graph where the trails are represented as edges and the trail junctions as nodes. Network analysis also helps in identifying potential connectivity issues, dead-end trails, or loops that might impede the usability of the hiking routes (De Smith et al., 2007). Hanna and Culpepper (1998) examined the topological errors associated with hiking routes such as disconnected trails, overlapping trails and trail segments that do not connect properly.

Mobile GIS applications have been revolutionized the way of experiencing hiking. These applications leverage the power of smartphones and GNSS technology integrating spatial data with user-friendly interfaces to

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enhance safety, navigation, and overall enjoyment on the trail. However, it is crucial to keep an internet database of tracking routes to create them though routes are already available in several countries via online platforms (Calbimonte et al., 2020). Generally, cellular network coverages can be unreliable, particularly in remote wilderness areas. Therefore, mobile GIS applications with offline map capabilities allow users to download trail maps and other relevant spatial data directly to their smartphones before embarking on their hike. This ensures continued access to crucial navigation information even in areas with limited or no internet connectivity (Patterson and Dawson, 2009). Offline maps downloaded beforehand allow hikers to plan their routes meticulously, visualizing potential challenges and identifying points of interest along the way (Huang et al., 2017). Another important issue is the battery of the smart phone. The battery can drain rapidly with the continuous relying on GNSS and internet connectivity for navigation. Offline mapping mode is the ideal solution for these issues (Stollberg et al., 2017).

Many mobile GIS applications offer real-time GNSS tracking features. These features allow users to track their location on the trail, providing a visual representation of their progress and estimated time of arrival at their destination. This information is not only valuable for the users but it can be shared with friends, family, or emergency services in case of an incident, promoting a sense of safety and security on the trail (Phillips et al., 2017). In the unfortunate event of a mishap on the trail, real-time GPS tracking data can be critical for search and rescue operations. By sharing their location data with emergency services, injured or lost hikers can significantly improve the chances of a swift rescue (McCrory et al., 2017). Group tracking functionalities provided by mobile GIS applications enable hikers exploring the trails together to visualize each other's locations on a map, promoting better coordination and ensuring nobody gets separated from the group, particularly beneficial for larger hiking groups or those venturing into unfamiliar territory (Wang et al., 2019).

METHODOLOGY

The methodology applied in this research is a mixed-method approach designed to enhance hiking tourism in Horton Plains National Park, Sri Lanka (Figure 1). Beginning with extensive data collection from various sources, including government agencies and hiking club members, the methodology integrates practical considerations and experiential knowledge. It includes the creation of a purpose-built trail network dataset, network analysis for identifying shortest paths, and detailed route analysis using Google Earth Pro Software package.

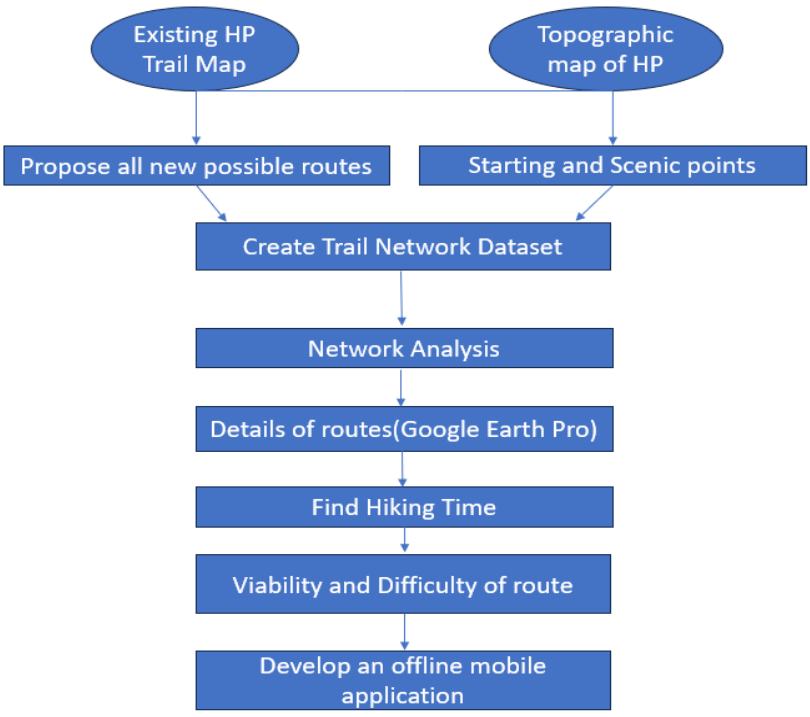

Figure 1: Flow Chart of Methodology

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Study Area

Horton Plains National Park is located in between the latitudes 6°47' to 6°50'N and longitudes 80° 46' to 80° 50' E and is located in the southern portion of the Nuwara-Eliya District, on a plateau in the southeast corner of Sri Lanka's central mountain range (Figure 2). The altitude varies from 2100 to 2300 meters and this plain gives a rise to the island's second and third highest mountains, Kirigalpotta (2389 m) and Totupola (2357 m) respectively. In 1969, 3162 hectares was designated as a Nature Reserve, and in 1988, it was re-classified as a national park. The park attracts many local and foreign visitors due to its diversified scenery, pleasant climate, floral and faunal heritage, and a variety of geomorphological features. Also, the area has made a pleasant scenario with the specific areas such as World's End which is considered as a look down from the cliff's edge, red bridge, chimney pool, Baker's water fall and Small World's End (Rathnayake, 2015).

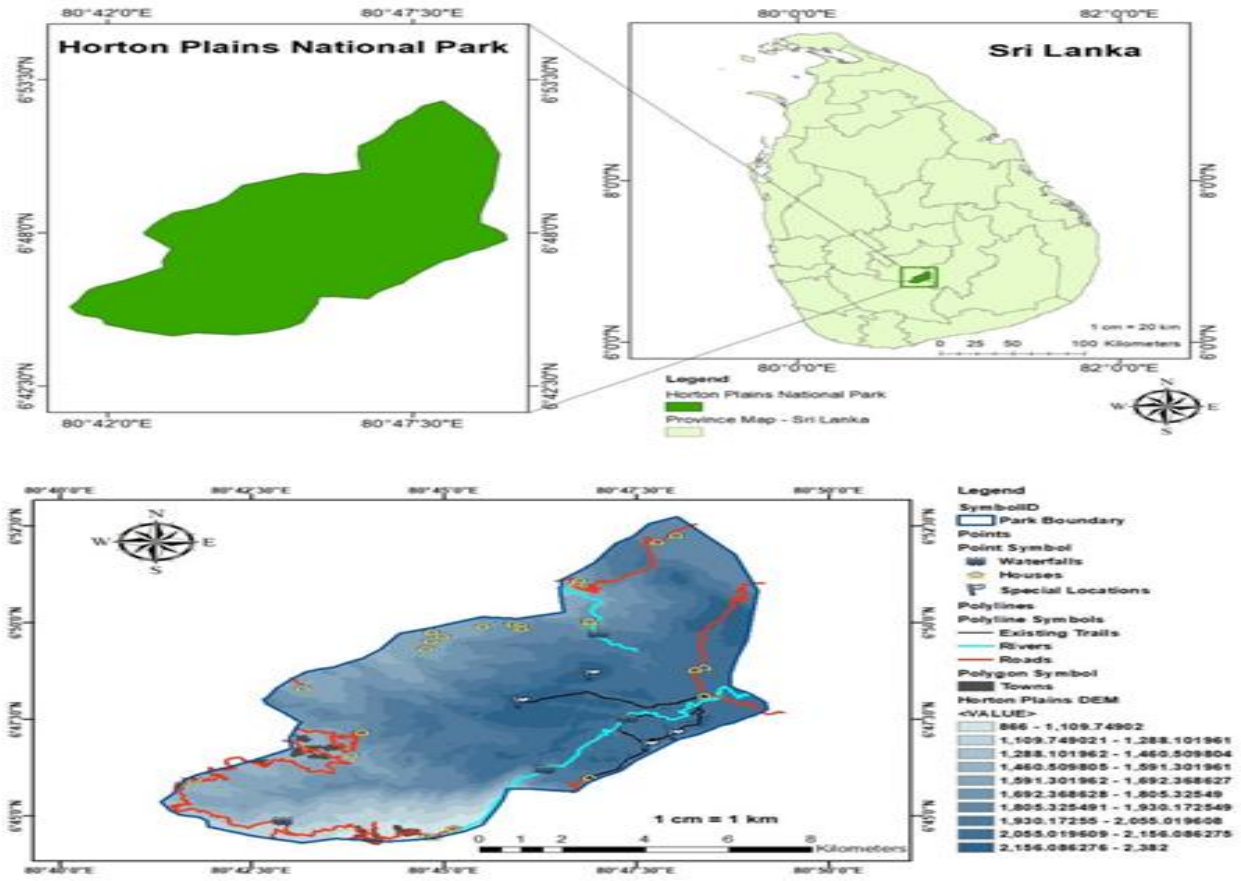

Figure 2: Study Area - Horton Plains National Park, Sri Lanka

Data for this study were collected from different sources. The GIS shapefiles on Hydrological features, utility infrastructure, existing buildings and transportation networks and Toponym and Terrain Data were obtained from the Survey Department of Sri Lanka, the national mapping agency of the country. Data such as information about the boundaries and ecological zones within the park, data on designated scenic points and existing routes within the national park were collected from the Wild Life Conservation Department of Sri Lanka.

In the course of this research, the creation of new and engaging hiking routes within Horton Plains National Park involved a meticulous manual digitizing process in GIS environment. The design of these routes prioritized various factors, starting with an in-depth contour mapping analysis (Figure 3). This ensured that the routes seamlessly followed the natural topography of the park, offering hikers a visually appealing and immersive experience. During the analysis of existing trails, two fundamental characteristics were discovered. Most of these trails follow either a ridgeline or a valley line in hilly terrains and the trails follow contour lines on flat terrains.

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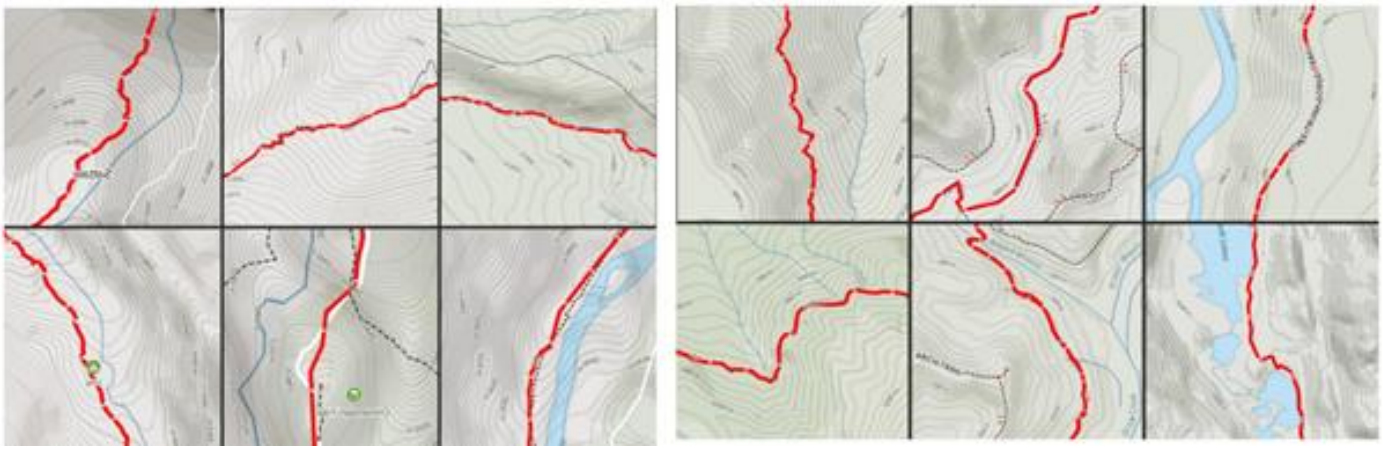

Figure 3: Trails on ridgelines and along contour lines

Importantly, when designing the hiking routes investigated the implementation of safety measures in Horton Plains National Park to ensure the well-being of both hikers and wildlife. In this process, prioritizing the avoidance of restricted zones and animal pathways within the research area. This was a thoughtful choice to make sure everyone stays safe and respects the wild animals. It's all about being responsible and taking care of the park, following principles of good tourism and conservation. In this design process, the slope was considered and fine-tuned the routes in order to avoid excessive steep or challenging terrains. This approach accommodated hikers with varying skill levels, contributing to a more inclusive and enjoyable hiking environment. Additionally, the routes were tailored to accommodate different distances and elevation gaps, providing options that catered to a diverse range of preferences and fitness levels.

Another key consideration in the route design was the availability of water along the paths. Water bodies were strategically incorporated into the routes, not only ensuring hiker's comfort but also adding to the scenic beauty of the proposed paths. The design process also took into account diverse landscape features, including viewpoints, lush greenery, and distinctive landmarks, enriching the overall hiking experience.

The manual design process allowed for flexibility, enabling the inclusion of unique features and points of interest discovered during field visits and collaborative efforts with local hiking clubs. This hands-on approach prioritized safety, accessibility, and a connection with the natural beauty of Horton Plains National Park. The result is a thoughtfully curated collection of new routes, providing hikers with an array of choices that showcase the park's unique characteristics while.

During the selection of start points, different number of factors were taken into account. Entrance to the hiking trail must be quick and accessible from all potential starting sites. An urban area, a guest house, a public use facility, or a car parking space must be closed to the starting points. Considering these factors, five main starting points were identified in the park. Endpoints are natural area markers (such as a mountain top, a monument, a waterfall, spring, etc.). As a result, 11 endpoints in the study area were identified.

In the process of translating the manually designed hiking routes into a functional network dataset, a challenge emerged in the form of topology errors. Employing the robust capabilities of ArcGIS software package, a solution was successfully implemented. Initially, the manually crafted network was transformed into a shapefile format. Subsequently, this shapefile was imported into the ArcGIS software and integrated into a personal geodatabase**.** Within the geodatabase, a new feature dataset was established to organize the spatial data effectively. Multiple feature classes, encompassing various elements of the hiking routes, were then imported into this dataset. To address and rectify topology errors, a new topology was created, outlining specific rules within the feature classes. The topology menu coupled with the Error Inspector tool, played a pivotal role in identifying and resolving topology issues. Notably, the "Extend Line or Dangle Length" function within the Error Inspector tool was utilized to trim lines and eliminate topology errors. Experimentation with different values for the dangle length parameter allowed for precise error correction.

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Once all topology errors were diligently corrected, the next step involved the construction of the network dataset. This was achieved using the "New Network Dataset" tool, leveraging the refined spatial data. The successful resolution of topology errors ensured the creation of a robust network dataset, laying the foundation for subsequent network analysis and the optimization of hiking routes within Horton Plains National Park.

Network Analyst in ArcGIS was used to figure out the shortest paths between the starting and ending points on the hiking trails considering travel time and length of the path. Restricted areas, such as locations unsuitable for hikers, were excluded from the analysis. Upon execution of the analysis, the software employed sophisticated algorithms to determine the optimal routes connecting the designated start and end points. These algorithms factored with various aspects including trail slope and elevation variations. The results were then shown on the map, highlighting the paths with all the details such as distances and changes in elevation. Elevation Profile function in Google Earth Pro was used to identify the aspects such as route length; elevation gain and average slope. The results were meticulously examined to ensure their validity and alignment with the research objectives. If necessary, adjustments were made to the analysis parameters or alternative routes were explored to enhance the accuracy.

The viability of each proposed routes was determined using their difficulty and expected duration. In this, the parameters such as the number of hours required to complete a route, the length of the trail, the total elevation gain, and expected average speed were considered (Colorado, 2001). In order to calculate the travel time for a route, following equations which were introduced by Vías et al. (2018), were used (*Equation I and Equation II*).

$$If\ TV > TH \rightarrow Time = TV + (TH/2) \ldots \textit{Equation I}$$

$$If\ TH > TV \rightarrow Time = TH + (TV/2) \ldots \textit{Equation II}$$

Where T_H (horizontal time) - the time taken to cover a specific horizontal distance

T_V (vertical time) - the time taken to achieve a specific vertical distance.

The estimated route difficulty is been provided as a reference to hikers and serves as a limit for trail improvement. If the time taken is less than three hours, that route was considered as a low difficult route and if it is in between three to six hours, that route was considered a moderate difficult route. Route which takes six to nine hours, those routes were considered as high difficult route. Routes having an expected duration of more than nine hours were not recommended in this study due to security and practical reasons.

The application follows a structured process to ensure user-friendly navigation and offline accessibility. The user interface was designed for ease, displaying the present location and available starting points initially. The design of the mobile application for hiking trails in Horton Plains National Park was developed using the Flutter framework. To input the trial vector data into the mobile application, the NetCDF file format was utilized. This format facilitated the integration of spatial data, including coordinates and trail attributes, into the application's database. The use of NetCDF allowed for efficient handling and storage of complex geographic information, ensuring accurate representation and navigation of the park's trails within the mobile app. This approach supported the overall objective of creating a user-friendly and interactive platform for hikers to explore and navigate the diverse trails.

Through this approach, hikers can select a starting point, explore scenic routes, choose a destination, and view the selected path using the offline map. The application leverages GPS technology to enable users to track their chosen route offline, contributing to a personalized and accessible exploration of the natural beauty. Once the user chooses a hiking trail, the app takes them to the Google Maps application. Upon selecting a destination point, the application seamlessly shifts to a map viewer interface. Here, the chosen hiking route is visually depicted on the map, offering users a clear representation of the path they intend to follow. Offline functionality enables users to track the selected path using the GPS enabled mobile phone, ensuring uninterrupted navigation even in areas with limited or no internet connectivity.

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RESULTS AND ANALYSIS

The significant results of this research hold the potential to completely remake the hiking experience in Horton Plains National Park of Sri Lanka. During the selection of starting points, several factors were considered. Firstly, prioritized were starting points that facilitate quick access to the trails for hikers (Figure 4). This approach ensures a smooth start to the hiking journey, enhancing convenience and ease for hikers.

Secondly, starting points were selected based on their proximity to towns or cities, ensuring accessibility for all types of hikers (Figure 4). Additionally, consideration was given to the availability of guest houses, public facilities, or nearby parking areas to enhance overall convenience and comfort for hikers. The assessment also included transportation services and ease of reach from different locations. By locating starting points near amenities and facilities, essential services and resources can be easily accessed by hikers before embarking on their hiking journey. These considerations led to the identification of five main starting points in the study area.

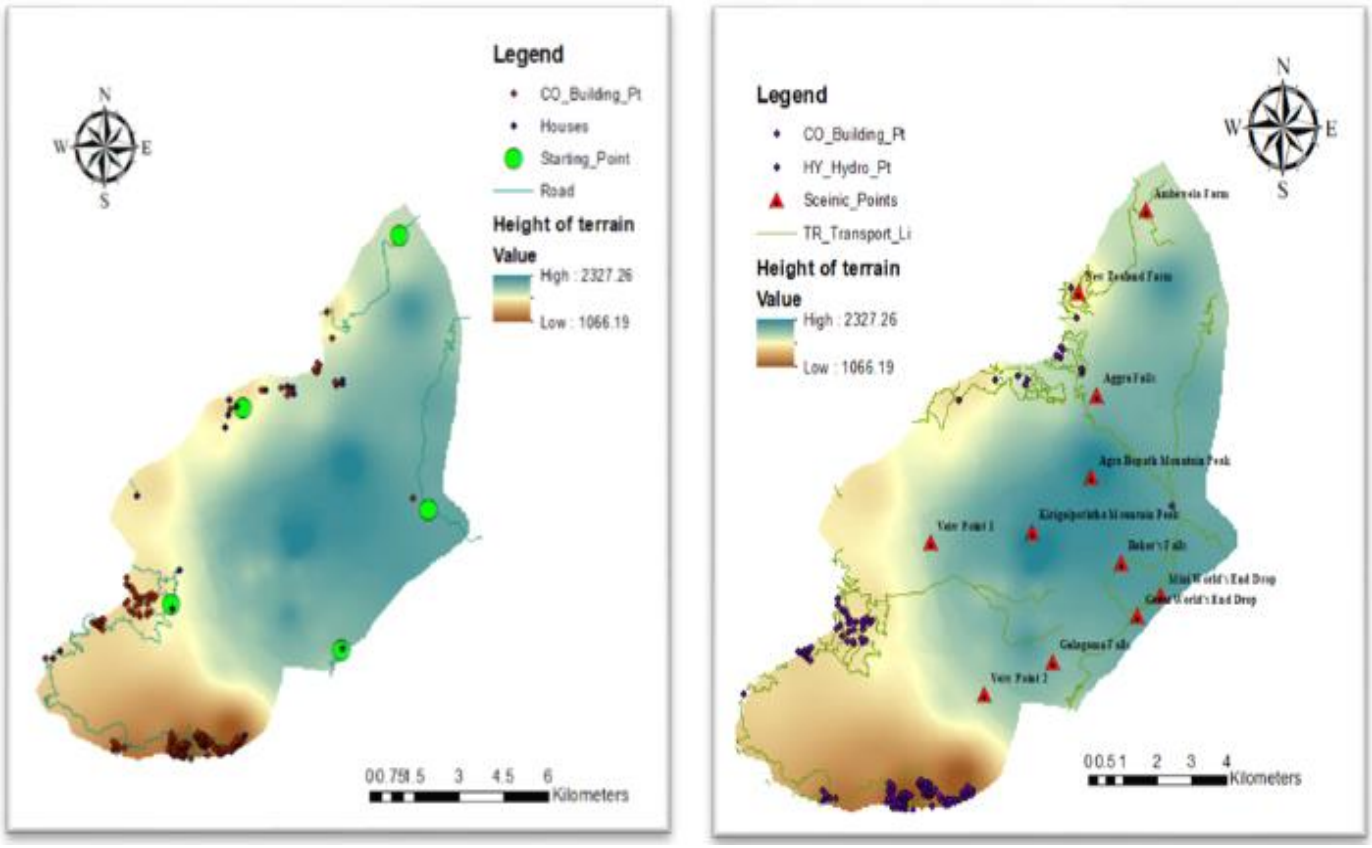

Figure 4: Starting Points and Scenic points

The study identified scenic points in the park area after having discussions with the hiking club members and experienced hikers. Recommendations and insights from outdoor enthusiasts were considered, leveraging their knowledge of well-known locations. Horton Plains National Park's manual route network process started with extensive data collecting, including topography maps, land use maps, and contributions from a range of sources, including members of hiking clubs. Utilizing topography maps, a contour plan was designed, laying the groundwork for the manual creation of possible routes. These routes were carefully designed, taking into account slope, contour maps, hydrological features, and the exclusion of prohibited areas.

The network dataset is an essential part of this research since it allows for effective route planning and analysis in the park. The network dataset, created with GIS software and manually planned routes, provides a thorough spatial representation of the hiking paths (Figure 5). It ensures the accuracy and integrity of the linked routes by applying topological rules and resolving any mistakes. This dataset plays a crucial role in network analysis, making it possible to determine the best routes, lengths of time, and other important factors for hikers exploring the national park's varied landscape.

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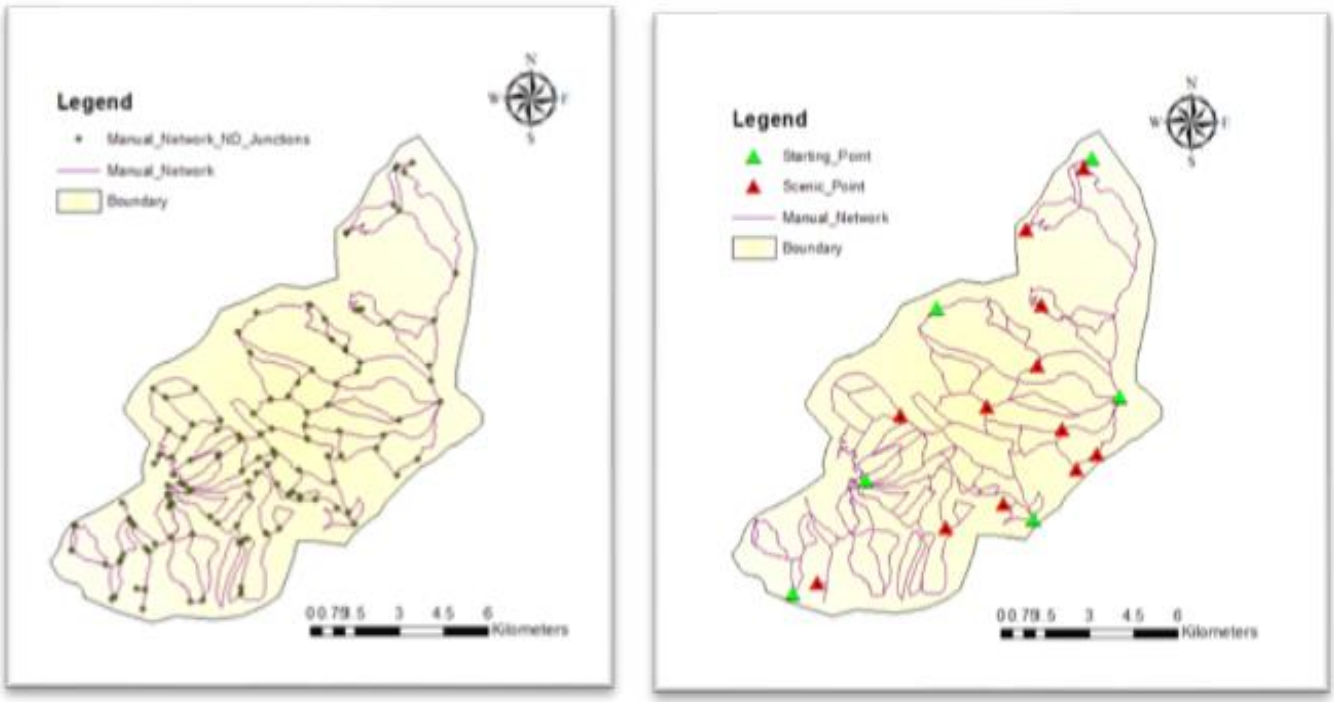

Figure 5: Manual Routes and Network Data Set

The network analysis step played a pivotal role in uncovering the most efficient and shortest paths within the park, connecting the identified starting and ending points (Figure 6). Using the created network dataset, this procedure was employed advanced tools and algorithms to determine the best routes as shown below figures. ArcGIS Pro software was used to carefully extract the information of the hiking routes such as distance, elevation gain, average slope and hiking time that were found after the network analysis.

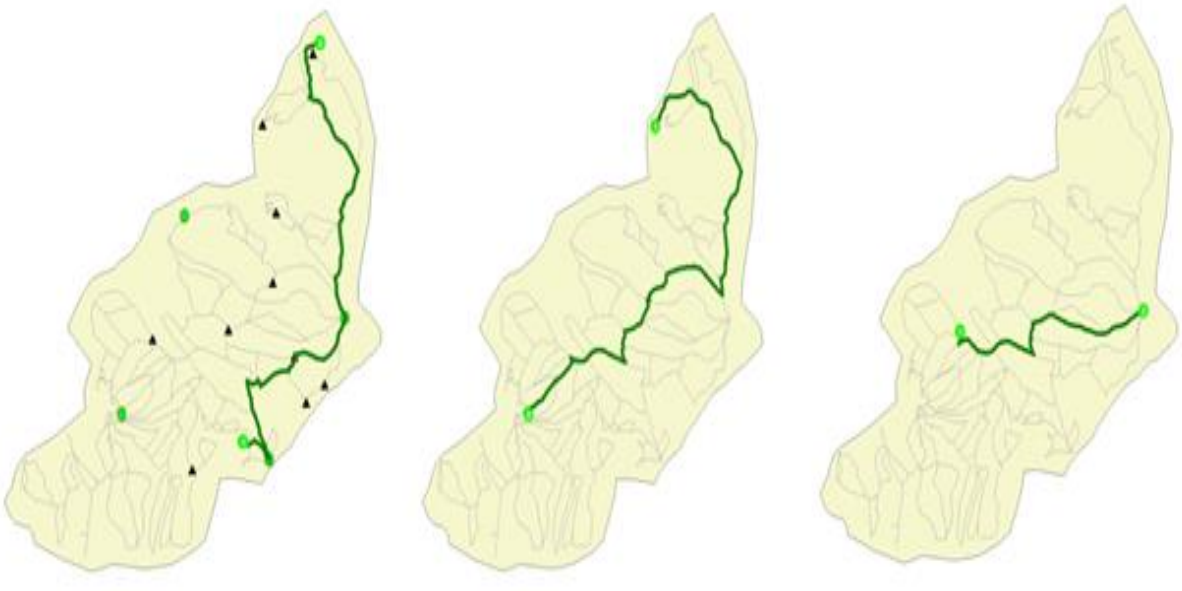

Figure 6: Network Analysis

The development of the mobile application was deemed crucial, as the application needed to ensure user-friendly navigation and offline accessibility (Figure 7). In the initial interface, users encounter a display showcasing their present location alongside all available starting points for hiking within the park. This empowers users to make an informed choice about their starting point, prompting the application to transition to the second interface in which users explore scenic points emanating from their chosen starting location.

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Each scenic point was intricately linked to various hiking routes, with detailed information such as distance, elevation gain, and estimated time provided.

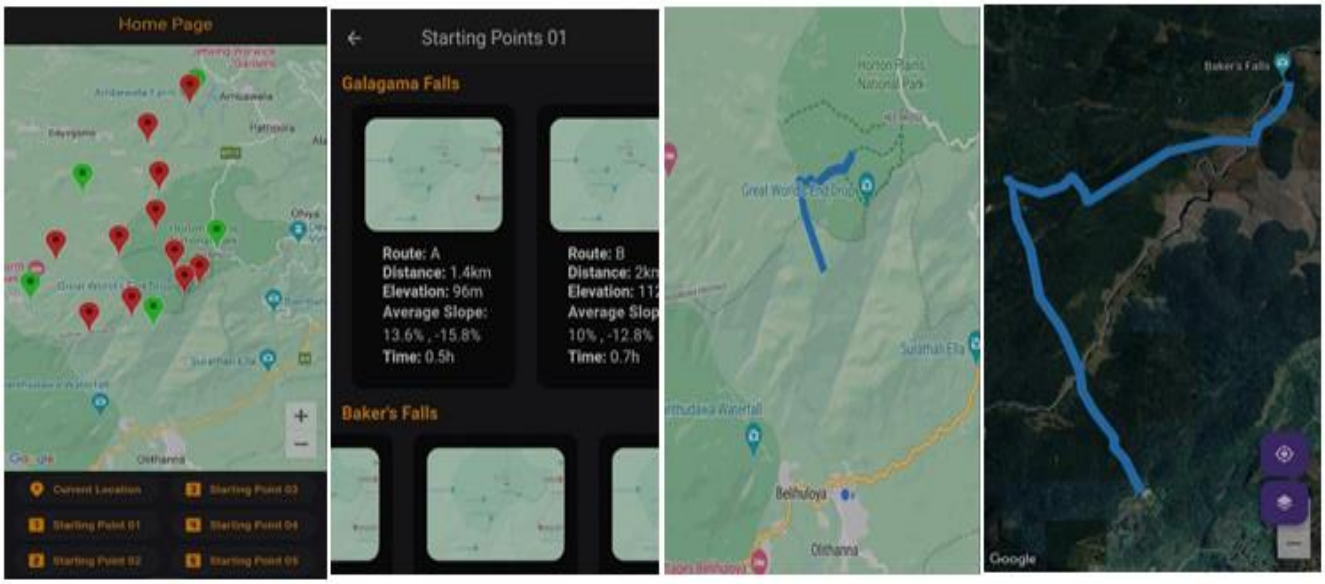

Figure 7: Initial Interface of application, different interfaces and map view of application

Upon selecting a destination point, the mobile application seamlessly shifts to the map viewer interface. The chosen hiking route is visually depicted on the map, offering users a clear representation of the path they intend to follow. Crucially, the offline functionality of the application enables users to track the selected path using the GPS receiver in the mobile phone, ensuring uninterrupted navigation even in areas with limited or no internet connectivity. The mobile application serves as a valuable tool, allowing users to customize their hiking adventure, access real-time information, and navigate offline, contributing to a more immersive and accessible exploration of the park's scenic trails.

DISCUSSION AND CONCLUSION

Hiking tourism is one of the fastest-growing forms of tourism globally. The number of hikers worldwide is estimated to be over 118.26 million, with global market size of $12.24 billion (Farad et al. 2017). This is an excellent opportunity for local governments to attract more tourists and bring them into their communities by providing hiking routes. The problem is that most tourists do not know where the hiking routes are available in local areas, making it difficult for them to plan their trips. A mobile application with hiking routes would solve this problem by allowing people to find out about the hiking trails near them without asking or searching online. Though there are many approaches introduced to promote hiking-related tourism activities worldwide, in Sri Lanka, it is very limited. Therefore, this research has shown a method to find and analyze hiking trails and utilize them on a mobile application.

The important of this study is the methodology applied for hiking trail recommendation system and analysis. It consists of 3 steps: identifying and propose all hiking trails, create the trail network dataset and analysis, and enriching the database with the details of the trails to recommend hiking trails with an offline mode mobile application. Google Maps application has been utilized to navigate along the hiking trails. The Google Maps offline map feature has been used to operate the trails in the locations without mobile data coverage.

In conclusion, the methodology proposed in this research to find hiking trails can be applied to any mountain, hill, or peak in Sri Lanka. The type of mobile application developed in this study can be used to guide the tourists in selecting their desired destination. Since the application will be available online, anyone can get an idea about the hiking destinations in Sri Lanka before coming. Hence, it will support the Sri Lankan tourism industry and, eventually, the country's economy.

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RECOMMENDATIONS AND FUTURE WORKS

This research applied manual methods to find new hiking trails. However, this method can lead human errors. Therefore, it is suggested to implement an automated method for this step. Hence the mobile application proposed in this study only serves the primary purpose, it is recommended to improve the mobile application to provide users a better experience. In this, finding new hiking trails using artificial neural networks and machine learning algorithms would be more efficient than manual method. The machine learning model can be trained using GIS data of hiking trails in a known location and Google Street View images for areas not covered by GIS data. Then the trained neural network on these inputs and outputs can predict which areas are not covered by GIS data but contain hiking trails. Using a Deep Neural Network and Dynamic Programming could be used to develop an automated method for detecting natural trails. This approach can be enriched by combining weather, soil, and location information to predict if a trail is dry or muddy. Also, the application can suggest similar hiking trails considering the user's previously liked trails.

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