GIS analysis of route along the Thailand-Myanmar border using topographic data: Implication for illegal immigration

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Abstract

This study delves into the intricate issue of illegal border crossings from Myanmar into Thailand, with a particular focus on the Thailand-Myanmar border region, renowned for its geographical diversity and porous boundaries. Employing Geographic Information Technology Systems (GIS) and Least Cost Path (LCP) analysis, the research aims to identify potential routes employed by individuals engaging in illegal border crossings. The study reveals that Tak Province in Thailand, specifically the Mae Sot District, stands out as a primary entry point for illegal immigrants. This phenomenon can be attributed to the region's distinctive geographic features and limited patrol capabilities. It also identifies other high-density routes in Chiang Rai, Kanchanaburi, and Ranong Provinces. Additionally, through a comprehensive examination of the Kanchanaburi-Myanmar border area, the research highlights the Ban Phra Chedi Sam Ong area as a designated high-risk zone for illegal immigration. Lastly, the research results illuminate areas that present less favorable conditions for foot travel when it comes to illegal border entry, particularly Ratchaburi and Phetchaburi Provinces. These regions are characterized by mountainous terrain and a lack of border communities, rendering them less accessible and unsuitable for travel and illegal activities. In conclusion, this research significantly contributes to a deeper understanding of the dynamics surrounding illegal border crossings between Myanmar and Thailand.

Keywords: Least Cost Path Analysis, Thailand-Myanmar Border, Cost surface, GIS

1. Introduction

The relationship between Myanmar and Thailand is profoundly entrenched and encompasses a broad spectrum of domains. This extensive relationship extends across diverse fields such as social sciences, geography, economics, commerce, diplomacy, and the military (Chemsripong, 2010). Both countries share a border that extends from the northern to the southern regions. This border region comprises ten contiguous provinces in Thailand that adjoin Myanmar: Chiang Rai, Chiang Mai, Mae Hong Son, Tak, Kanchanaburi, Ratchaburi, Phetchaburi, Prachuap Khiri Khan, Chumphon, and Ranong. The total length of the border spans approximately 2,400 kilometers. In addition to utilizing the established border checkpoints at Mae Sai, Mae Sot, and Ranong for entry and exit, there exist 14 temporarily permitted areas situated across five provinces (Department of Foreign Trade, 2012). The border area between Myanmar and Thailand exhibits a diverse topography, featuring various geographical elements such as mountains, plains, and rivers. This diversity in terrain creates multiple pathways for travel and trade between the two countries. While some of these routes are sanctioned and function as regular traffic channels at official border crossings, there also exist illicit routes employed for smuggling, where individuals traverse natural border paths that lack official designation (Caouette & Pack, 2002). Consequently, the challenges associated with prevention and surveillance are formidable. This issue represents a national concern that cannot be easily addressed, thus complicating efforts to provide comprehensive protection and surveillance along the entire border.

Over the years, Thailand has seen a rise in the influx of illegal trans-border laborers, cementing its position as one of the Asian countries coping with this issue. Thailand officially reported 1,394,446 trans-border laborers in 2016. This number was divided into 398,777 legal workers and 995,669 illicit workers. Individuals of Burmese origin represented the largest group of these migrant laborers, with an official count of 1,047,643, consisting of 325,191 with legal admission and 722,452 without legal paperwork. According to these data, around 60% to 70% of migrant laborers or trans-border laborers in Thailand are from Myanmar, with a substantial part of them entering the nation without official authorization. (Buadaeng & Sirasoonthorn, 2018). Within Thailand, there exists a complex network of illegal Myanmar migrant workers, intricately linked to an international network of brokers. These brokers play a pivotal role in facilitating the movement of individuals, identifying routes, and coordinating timings. This operation often entails collaboration between local politicians and capitalists, who join forces to establish unauthorized entry points into the country. The smuggling points employed by this network are diverse, ranging from navigating through unmonitored border forests to circumventing official checkpoints through alternative routes and finding refuge in concealed, inconspicuous temporary shelters. These locations are temporary and subject to frequent changes to evade detection. Additionally, they establish communication systems and prearranged appointments, providing support throughout the illicit entry process into the interior regions of Thailand (Leelachai & Spielmann, 2011).

When embarking on a journey, individuals typically consider their physical capabilities and the time available when deciding on a walking route. In other words, people generally opt for paths that require minimal exertion, energy expenditure, and travel duration. The utilization of GIS systems has led to the development of methods for analyzing and predicting the potential routes people might choose for their travels (Gowen & de Smet, 2020). When examining spatial analysis and geographic information systems in conjunction, one prominent method of study is the least cost analysis. This approach encompasses an economic principle that seeks to evaluate the efficiency of utilizing available resources to achieve optimal cost-effectiveness. It involves comparing all potential pathways and selecting the route with the lowest associated cost as the model's output (Schild, 2016). In the field of geographic applications, LCP analysis is frequently employed in conjunction with spatial analysis techniques. LCP analysis allows users to establish cost parameters that take into account various factors influencing movement or human travel. It serves as a method to simulate theoretical movement across the terrain, determining the most efficient and cost-effective path between a source and destination (Briney, 2014). The current study aims to identify areas that could have potentially served as optimal routes between locations by developing an LCP model (Contreras, 2011; Cortegoso et al., 2016; Gravel-Miguel & Wren, 2018; Güimil-Fariña & Parcero-Oubiña, 2015; Gustas & Supernant, 2017; McCoy et al., 2011; Taliaferro et al., 2010).

Numerous researchers have utilized LCP analysis to investigate previously unexplored pathways, with geographic information playing a pivotal role in analyzing travel patterns. This has sparked interest in applying this concept to simulate a spatial route along the border. In this study, the primary objective of this paper is to determine a potential travel route between the Thailand-Myanmar border (Figure 1) by analyzing an LCP from the Myanmar side to the Thailand side. Identifying the routes used by illegal border crossers can aid in threat mitigation efforts by enabling authorities to formulate targeted strategies to address these issues. By leveraging LCP analysis and integrating various approaches, relevant authorities can work toward mitigating threats and enhancing security in the border region (Rivera, 2014).

2. Material and Method

2.1. Material

Our investigation relies on a Digital Elevation Model (DEM) generated from the Shuttle Radar Topography Mission database. This DEM furnishes elevation data on a global scale with a spatial resolution of 3 arc-seconds (approximately 90 meters). Access to this data can be obtained through the Earth Explorer platform hosted by the U.S. Geological Survey at earthexplorer.usgs.gov. The analytical procedures were executed using ESRI's ArcMap 10.5 software. The downloaded DEMs were amalgamated or "mosaicked" into a unified DEM to ensure a seamless analysis.

Subsequently, this unified DEM underwent a re-projection into Universal Transverse Mercator units, employing the WGS 84 47 North coordinate system and datum. The distinction between land and sea was delineated using a shapefile sourced from the https://www.diva-gis.org/gdata website. The DEM data was clipped to align with these land and sea boundaries.

Furthermore, our methodology entails the selection of initial and final points for generating the LCP route based on village location data along the Thailand-Myanmar border. The selection process is guided by observations of villages located closest to the border in both countries. We utilize the Google Earth program for visual assessment of these villages and strategic placement of points to ensure comprehensive coverage of the area. Consequently, we have identified and chosen a total of 50 villages in Myanmar and 50 villages in Thailand along the border, spanning from north to south.

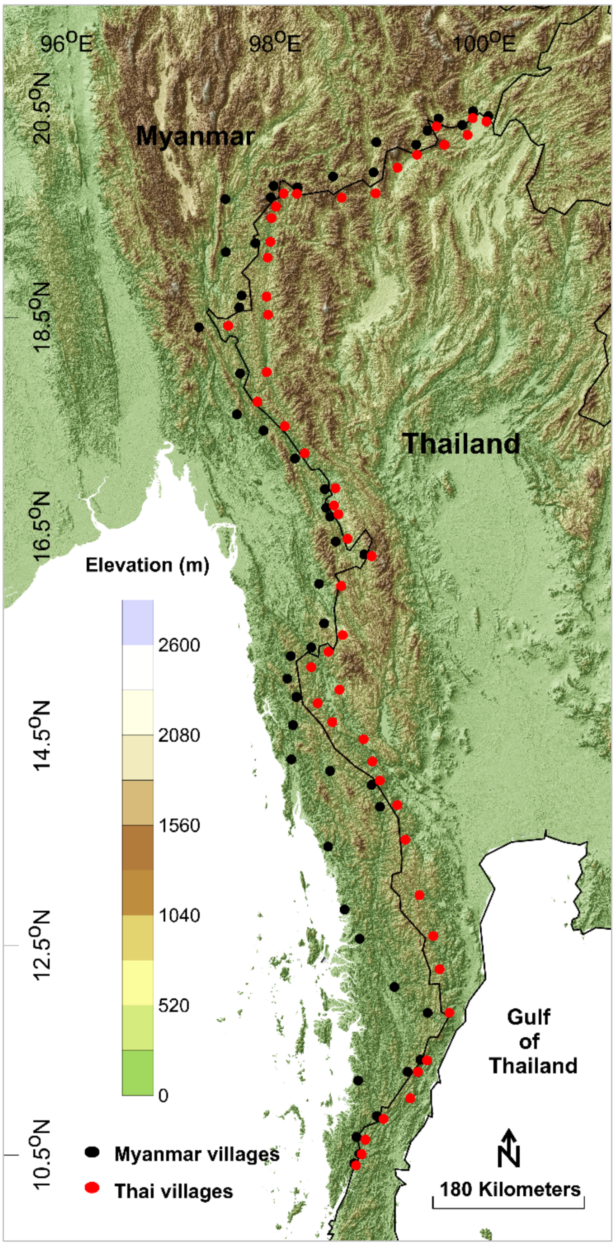

Figure 1. Map of the study area showing the topography of the Thailand-Myanmar border mentioned in the text. Black dots represent a case study of villages in Myanmar, and red dots represent a case study of villages in Thailand.

This approach leverages both remote sensing technology and GIS to enrich the analytical process. By utilizing Google Earth, we gain access to high-resolution satellite imagery and geospatial information, enabling precise pinpointing of village locations and an enhanced understanding of the geographical context. This data, in conjunction with your DEM and GIS tools, facilitates the efficient calculation of the LCP route, taking into account factors such as elevation, terrain, and accessibility.

2.2. Method

While the LCP model may not have been extensively utilized in studies specifically dedicated to illegal immigrant dispersals out of Myanmar, it has indeed found applications in simulating routes taken by illegal immigrants along the borders of other countries (Rivera, 2014). Additionally, this method has been extensively employed for modeling human interactions and movements across various scenarios. For instance, it has been used to select routes for autonomous vehicles (Stahl, 2005), examine ancient pathways in archaeology (Herzog, 2010, 2013; Pingel, 2010), and investigate coastal migration into the Americas (Gustas & Supernant, 2019).

The fundamental concept underlying LCP is the determination of the optimal path between two points, achieved by minimizing the cumulative impact of impediments often referred to as costs. In this context, cost serves as a representation of the difficulty or resistance encountered during traversal of distinct terrain types, and its quantification can vary according to factors under consideration, such as distance, slope, land cover, and more (Herzog, 2014; Howey, 2011; Howey & Burg, 2017). The assessment of cost within the framework of LCP exhibits considerable variability, contingent upon the specific factors involved. Data attributed to different segments of the landscape is utilized to compute the cost associated with traversing those areas. This cost can represent various elements, including time, energy, or a combination thereof. For instance, when applying LCP to travel or navigation analysis, the cost might represent the time or energy it takes to move through different types of terrain (Kantner, 2008). Areas characterized by steep slopes, dense vegetation, or water bodies typically incur higher costs due to their elevated traversal difficulty, demanding more time and exertion. In contrast, flat terrain or open expanses generally entail lower costs.

Traditionally, the most frequently utilized input parameters for LCP modeling have been slope and/or land cover (Byrd et al., 2016; Contreras, 2011; Cortegoso et al., 2016; Howey, 2007, 2011; Siart et al., 2013).

In this study, we intentionally excluded significant environmental factors like vegetation cover and the influence of water on route selection through the landscape. Additionally, the study does not consider the presence or absence of infrastructure, such as roads or the availability of river transport. When conducting a comprehensive examination of movement patterns within a specific geographical region, with a particular emphasis on mapping precise routes, it becomes essential to incorporate these factors. However, in our investigation, the generation of LCPs through the utilization of a cost surface aims to forecast broad movement patterns over a vast region spanning hundreds of thousands of square kilometers. To illustrate our approach, we created a journey using slope-dependent LCP modeling and presented it as a raster in ArcGIS 10.2, allowing for visual interpretation. The Thailand-Myanmar border features an extensive mountainous topography that strongly shapes the landscape. These mountain ranges have a substantial impact on the geography, climate, and human activities in the border area. Utilizing a cost surface based on slope and elevation is particularly fitting for comprehending movement patterns in large regions characterized by mountains and valleys. Given that the peaks and steep slopes of mountains can significantly impact movement, focusing on the valleys as potential routes is a sensible strategy (Rees, 2021).

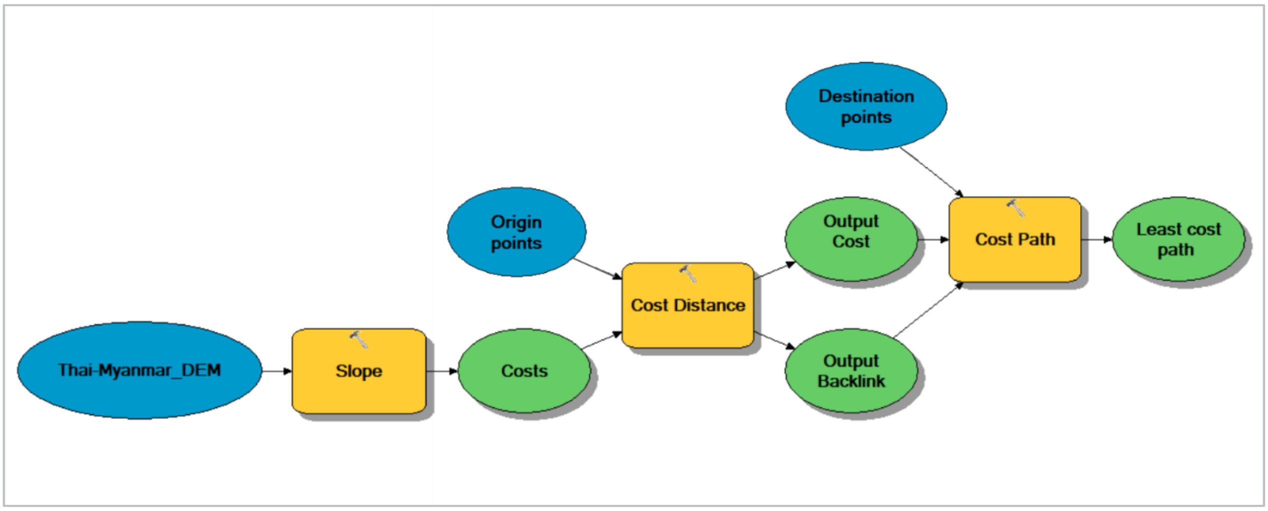

Figure 2. Methodological flowchart for LCP

Establishing an LCP route involves several key stages, as illustrated in the flowchart presented in Figure 2. The process begins with the generation of a cost distance raster as the initial step. This involves utilizing slope values and initial point data to calculate the least accumulative cost distance for each cell from or to the least cost source across a cost surface. Following that, proceed to produce the cost-backlink raster. The data to be evaluated during this process includes the slope and starting point, similar to creating a dataset for cost distance. Both rasters make use of the cost distance (spatial analysis) tool. The dataset derived from the previous steps is employed to establish an LCP route through the utilization of the cost path tool. This tool calculates the path in raster format, starting from the source and leading to the destination. Ultimately, the raster to polyline tool is employed to convert the cost path from its original raster format into polyline format.

3. Results

3.1. Thailand-Myanmar Natural Border Path

The outcomes of the LCP analysis are visually represented in Figure 3 for the Thailand-Myanmar natural border path. The analysis has unveiled various noteworthy patterns related to illegal immigration in border areas. As anticipated, when simulating routes originating from each village on the Myanmar side to all corresponding villages on the Thailand side, the majority of routes emanating from neighboring villages in both countries intersect at the border, representing the shortest geographical distance between them. Nonetheless, there are certain areas where, despite the proximity of village locations, the LCP route opts to initially traverse the plains in Myanmar before proceeding along the plains along the mountain ridge, eventually crossing the border. This phenomenon is particularly evident in the border region between Phetchaburi Province and Ratchaburi Province.

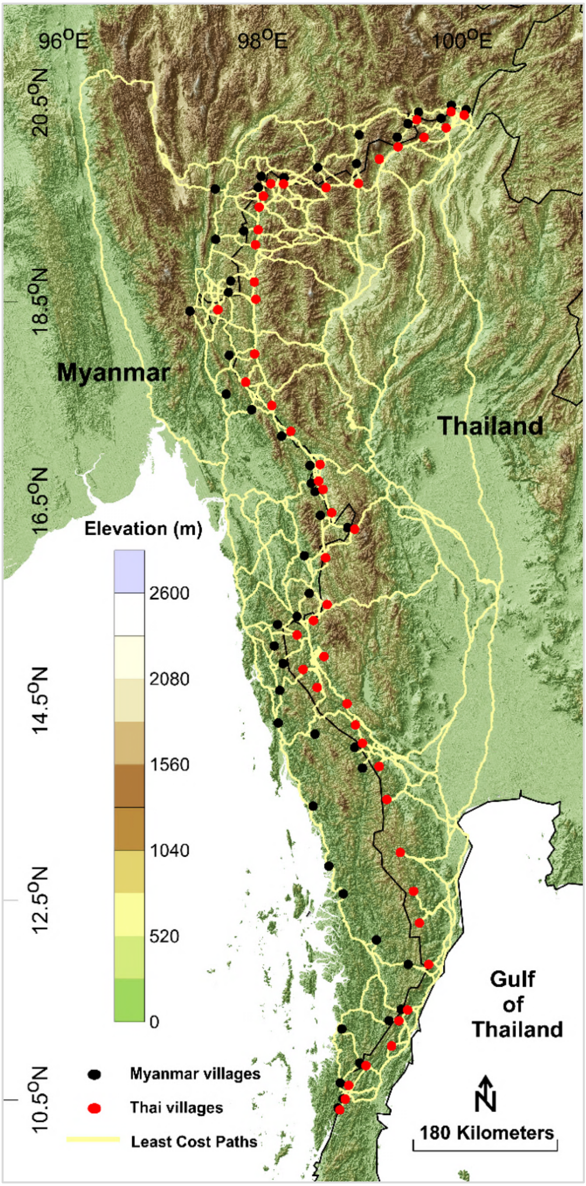

Figure 3. Results of the LCP for the Thailand-Myanmar natural border path.

This process involved the simulation of routes from villages in Myanmar to villages in Thailand, resulting in a total of 92 routes that crossed the border. These border-crossing routes are distributed across nearly every province along the border, except Ratchaburi and Phetchaburi (as detailed in Table 1). The results unequivocally demonstrate that multiple routes traverse the border areas in various provinces. Chiang Rai Province boasts 13 border-crossing routes, spanning Chiang Saen District, Mae

Sai District, and Mae Fa Luang District. Chiang Mai Province features six routes in the border areas of Mae Ai District, Chiang Dao District, and Wiang Haeng District. In Mae Hong Son Province, there are 26 routes in the border areas of Pang Mapha District, Mueang Mae Hong Son District, Khun Yuam District, Mae La Noi District, Mae Sariang District, and Sop Moei District.

This analytical approach effectively generates a heat map illustrating areas that should have been more heavily traveled according to the model's predictions (Figure 4).

Table 1. The tally of border crossings spanning the boundary between Thailand and Myanmar within the various districts of each province.

Province	District	Sub-district	Location of District		Number of border crossing routes
			Latitude	Longitude	
Chiang Rai	Chiang Saen	Wiang	20.313	100.092	1
	Mae Sai	Koh Chang, Mae Sai	20.446	99.908	6
	Mae Fa Luang	Mae Fah Luang, Thoet Thai, Mae Salong Nai	20.323	99.640	6
Chiang Mai	Mae Ai	Tha Ton	20.120	99.200	1
	Chiang Dao	Mueang Na	19.723	98.957	3
	Wiang Haeng	Piang Luang, Mueang Haeng	19.694	98.625	2
Mae Hong Son	Pang Mapha	Pang Mapha, Na Pu Pom,	19.694	98.223	6
	Mueang Mae Hong Son	Huai Pha, Mok Champae, Pang Mu, Pha Bong	19.581	97.945	6
	Khun Yuam	Khun Yuam, Mae Ngao	19.049	97.799	3
	Mae La Noi	Mae La Luang	18.559	97.823	1
	Mae Sariang	Mae Khong, Sao Hin	18.472	97.446	8
	Sop Moei	Mae Sam Laep	17.943	97.748	2
Tak	Tha Song Yang	Tha Song Yang, Mae Song, Mae Tan, Mae La	17.301	98.179	8
	Mae Ramat	Mae Ramat, Mae Cha Rao	16.876	98.544	4
	Mae Sot	Tha Sai Luat, Mae Tao, Mae Ku	16.591	98.605	6
	Phop Phra	Chong Kab, Wale	16.358	98.694	4
	Umphang	Mae Chan, Mogro	16.087	98.828	4
Kanchanaburi	Sangkhlaburi	Lai Wo, Nong Loo	15.278	98.423	7
	Thong Pha Phum	Pilok	14.679	98.372	1
	Sai Yok	Sai Yok, Bong Ti	14.050	98.988	3
	Mueang Kanchanaburi	Ban Kao	13.913	99.083	1
Prachuap Khiri Khan	Mueang Prachuap Khiri Khan	Ao Noi, Khlong Wan	11.767	99.665	2
	Bang Saphan	Chaikasame, Ron Thong	11.311	99.344	2
Chumphon	Tha Sae	Rab Ro	10.838	99.022	1
Ranong	Kra Buri	Pak Chan, Nam Chuet Noi	10.580	98.838	4

Tak Province encompasses 26 routes in the border areas of Tha Song Yang District, Mae Ramat District, Mae Sot District, Phop Phra District, and Umphang District. Kanchanaburi Province includes 12 routes in the border areas of Sangkhlaburi District, Thong Pha Phum District, Sai Yok District, and Mueang Kanchanaburi District. Prachuap Khiri Khan Province has four routes situated in the border areas of Mueang Prachuap Khiri Khan District and Bang Saphan District. Chumphon Province has one route in the border area of Tha Sae District.

Lastly, Ranong Province comprises four routes in the border area of Kra Buri District. Moreover, in conjunction with simulating the LCP to visualize potential individual routes, these paths can be superimposed to calculate line density. Line density is a metric that quantifies the frequency with which paths traverse a specific cell (ESRI, 2016).

In essence, while the LCP represents the possible routes generated by the model, the density analysis highlights the area most likely to be utilized for movement. The results of the line density analysis, as depicted in Figure 4, illustrate regions that exhibited higher levels of traversal, as indicated by warmer colors, as well as regions that were less frequently traveled, represented by cooler colors, according to the model. The findings reveal that the region with the highest border crossing route density is situated in Tak Province (Figure 4b). This elevated density is particularly notable in various sub-districts, including Mae Cha Rao in Mae Ramat District, Tha Song Yang in Tha Song Yang District, and several sub-districts in Mae Sot District, such as Mae Kasa, Mae Pa, Ta Sai Luat, Mae Tao, and Mae Ku. Alongside Tak Province, the density results emphasize areas like Wiang Sub-district and Si Don Mun Sub-district in Chiang Saen District, Chiang Rai Province (Figure 4a), as well as Nong Lu Sub-district in Sangkhlaburi District, Kanchanaburi Province (Figure 4c), and Pak Chan Sub-district in Kra Buri District, Ranong Province (Figure 4d). These regions also exhibit the next highest density of routes.

3.2. Kanchanaburi Natural Border Path

Building upon our initial work of simulating routes along the entire Thailand-Myanmar border, we intend to undertake a more comprehensive analysis of the Kanchanaburi-Myanmar border area. This phase of the study entails the inclusion of additional meticulously identified village locations from both countries, thereby expanding the scope of our route simulations. In this more focused analysis, we have identified nine Myanmar positions and 12 positions on the Kanchanaburi side (Figure 5). Remarkably, our route simulations revealed that all 17 routes passed through the Kanchanaburi-Myanmar border (as detailed in Table 2). Sangkhlaburi District has six routes that cross the border, located in Lai Wo Sub-district and Nong Lu Sub-district. Thong Pha Phum District has two routes, situated in the Pilok Sub-district and Lin Thin Sub-district. Sai Yok District has five routes, covering areas in Sai Yok Sub-district, Wang Krachae Sub-district, Bong Ti Sub-district, and Srimongkhon Sub-district. In Mueang Kanchanaburi District, there is one route that crosses the border, found in Ban Kao Sub-district.

4. Discussion

The simulation of the LCP route along the Thailand-Myanmar border has revealed a plethora of routes in nearly every province along this extensive border. This proliferation of routes can be attributed to Thailand's extensive border with Myanmar, which stretches from the northern to the southern region and constitutes the longest border compared to those shared with neighboring countries, including Laos, Cambodia, and Malaysia (Bunyarin, 2020; Chemsripong, 2007). In each province, a variety of natural features serve as potential channels for illegal entry, including plains, rivers, mountains, and coastal areas along the sea. However, two provinces, Ratchaburi and Phetchaburi, stand as exceptions to this trend. In the case of Phetchaburi, the border area.

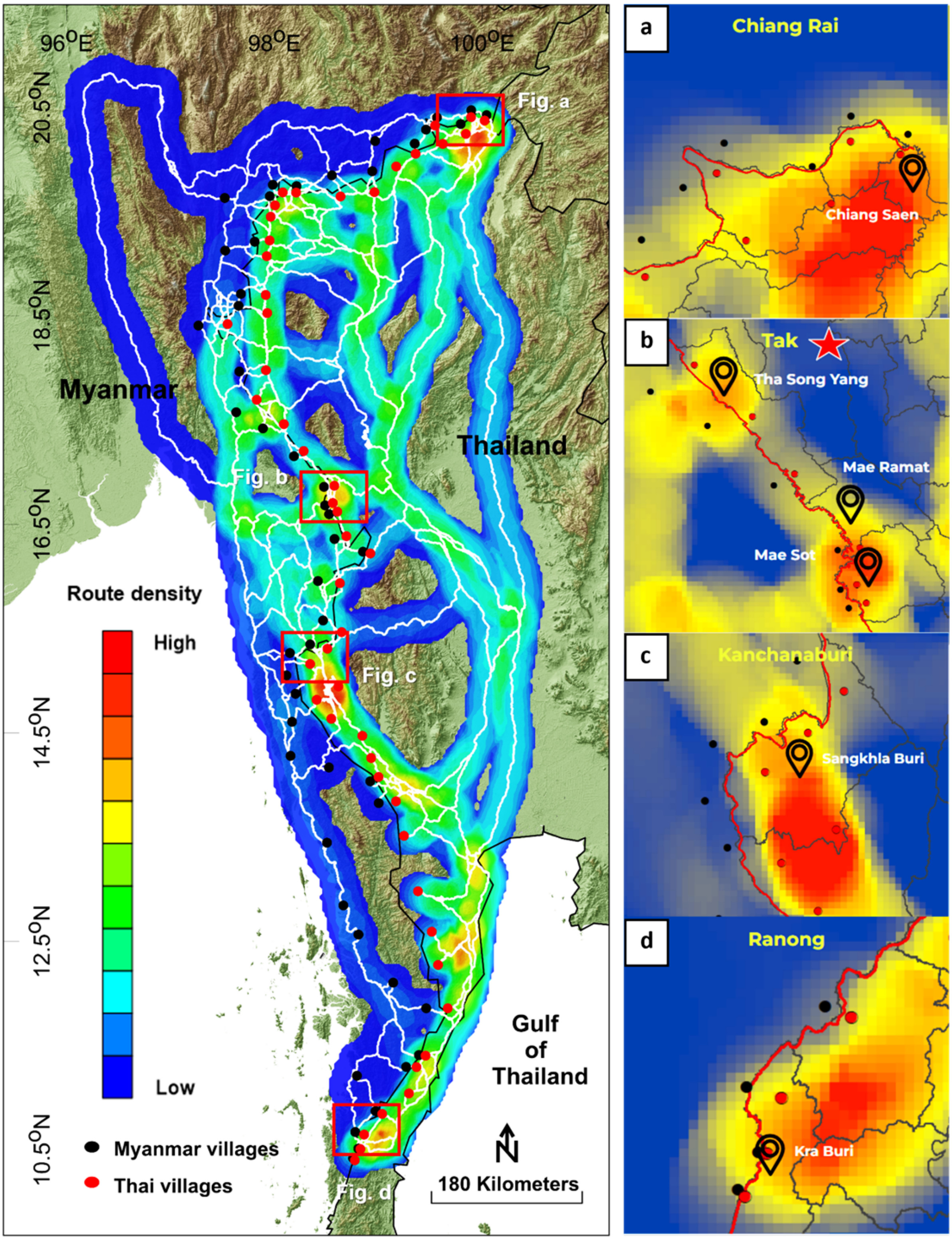

Figure 4. Density of LCP for the Thailand-Myanmar natural border path a) Chiang Saen border b) Tha Song Yang, Mae Ramat, and Mae Sot border c) Sangkhlaburi border d) Kra Buri border

Table 2. The geographical positions of border crossings occurring across multiple sub-districts situated along the Kanchanaburi-Myanmar border.

District	Sub-district	Village	Result output using LCP analysis	
			Latitude	Longitude
Sangkhlaburi	Lai Wo	Ban Ja Kae	15.527	98.572
		Lai Wo	15.368	98.538
	Nong Loo	Ban Phrachedi Sam Ong	15.297	98.410
		Songkalia	15.261	98.411
		Vaikadee	15.221	98.245
		Ban Mai Pattana	15.175	98.210
		Ban Mai Pattana	14.941	98.238
Thong Pha Phum	Pilok	Ban E-tong	14.709	98.338
		Ban E-tong	14.682	98.362
		Ban E-tong	14.665	98.367
	Lin Thin	Lin Thin	14.445	98.533
Sai Yok	Sai Yok	Sai Yok	14.340	98.594
	Wangkrachae	Ban Chai Thung	14.235	98.736
	Bong Ti	Thungmaseryoh	14.108	98.908
		Ban Thai Mueang	14.048	98.971
	Srimongkol	Ban Tha Kham Sud	14.013	98.995
Mueang Kanchanaburi	Ban Kao	Ban Phu Nam Ron	13.921	99.062

is situated within the confines of the Kaeng Krachan National Park, characterized by mountainous forest terrain that poses significant barriers to passage. Notably, neither the Thailand nor Myanmar sides of this area are inhabited by communities residing near the border. In the case of Ratchaburi Province, it is important to note that there is a lack of significant communities along the Myanmar border that directly abut Ratchaburi Province. Additionally, the presence of the Tanaosri mountain, which forms a 73-kilometer-long border, introduces substantial complexities to travel within this border region.

The findings of this study indicate that the region with the highest density of border crossings is situated in Tak Province. A thorough review of data obtained from government agencies reveals that a substantial 70 percent of Myanmar workers enter Thailand through the northern region. Among the provinces in this northern region, such as Chiang Rai, Chiang Mai, Mae Hong Son, and Tak, it was established that Tak Province functions as the primary conduit for Myanmar workers entering Thailand (ThaiPublica, 2021). Within Tak Province, the area with the highest incidence of illegal entry is Mae Sot District

This can be primarily attributed to the geographical feature of a narrow river that serves as the border between the two countries. The presence of small boats makes it relatively easy for individuals to cross, and the challenging terrain renders it difficult for officials to conduct effective patrols (Kamonwutipong, 2021). Furthermore, a previous study has been conducted to identify areas that serve as hiding places for illegal immigrants. These areas are predominantly located along Asia Highway routes 105 (Mae Sot-Tak) and 1175 (Mae Ramat-Baan Tak). These areas are conducive to illegal activities due to the limited number of inspection points and their remote nature, which results in a scarcity of personnel available for monitoring and enforcement (Buadaeng & Sirasoonthorn, 2018). These findings substantiate the observed density of routes in Mae Sot District and Mae Ramat District, as depicted in Figure 4. The data reveals a notable presence of LCP routes that extensively overlap in this region, often traversing the same routes multiple times. Furthermore, the results draw attention to Tha Song Yang District in Tak Province as another area characterized by a high density of border-crossing routes. An examination of the border topography in this region reveals a pattern where these high-density route areas are closely associated with villages positioned in proximity to the border. The Moei River serves as the principal demarcation line between these villages and Myanmar. This geographical configuration is considered favorable for smuggling activities into Thailand due to its relatively accessible nature.

According to the study's findings, in addition to Tak Province, three other provinces demonstrate the next highest density of routes along their border areas. These provinces encompass Chiang Rai Province's Chiang Saen District, where the border is demarcated by the Ruak River. This particular river, owing to its shallow and narrow features and the presence of dense communities and transportation routes on both sides, facilitates illegal crossings (MGR Online, 2020). In Kanchanaburi Province's Sangkhlaburi District, the border with Myanmar spans approximately 160 to 170 kilometers without definitive boundary markers, creating favorable conditions for illegal entry

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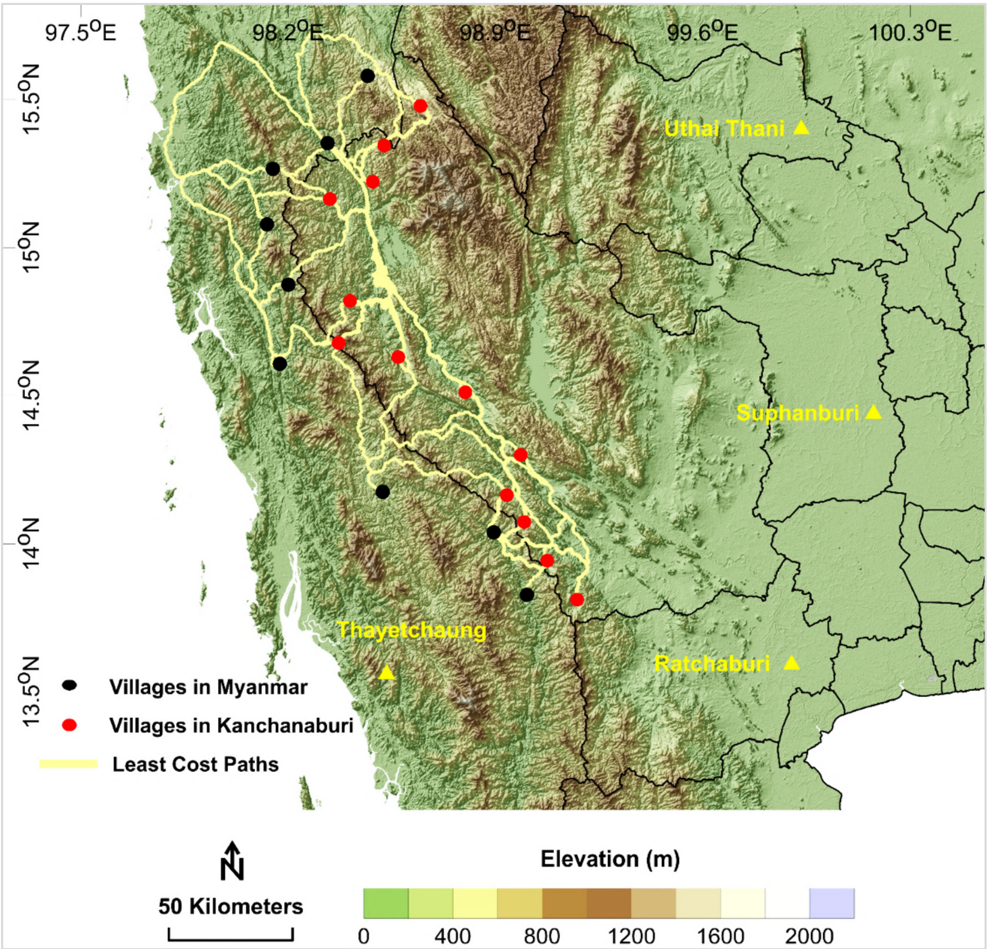

Figure 5. Results of the LCP for the Kanchanaburi-Myanmar natural border path

Accessible communication channels and a lack of significant obstacles contribute to this phenomenon. Furthermore, in Kra Buri District, Ranong Province, the Kra Buri River running along the border provides a gateway for illegal entry through the river and sea, leading to the Ranong Strait in Kawthaung, Myanmar (Bunyarin, 2020). These observations underscore the multifaceted role of geographical and environmental factors in contributing to the prevalence of illegal border crossings in these regions. A more comprehensive analysis of the Kanchanaburi-Myanmar border area reveals that the study's examination of LCP routes has identified a total of 17 routes intersecting the border. A closer investigation into the locations of natural border paths frequently utilized for illegal entry along the Kanchanaburi border, based on data sourced from Kanchanaburi Immigration, underscores the significance of these findings. Notably, out of the 17 identified routes, a substantial 11 align with these natural border paths. These paths encompass several specific areas, namely Ban Lai Wo, Ban Phrachedi Sam Ong, Ban Songkalia, the northern part of Ban Mai Phatthana, Ban E-Tong, Ban Thai Mueang, Ban Chai Thung, and Ban Phu Nam Ron. Among the 11 LCP routes identified, it is worth highlighting that the route passing through the Takhian Thong natural border path, located within the Ban Phra Chedi Sam Ong region, emerged as the most frequently utilized route. This observation aligns with the findings presented in the annual report of the Kanchanaburi Fishery Inspection Office, which designates the Phra Chedi Sam Ong Checkpoint area as a high-risk zone. The geographical conditions of the area give rise to natural border paths that run alongside roads in Thailand, providing relatively easy access for entry and exit. Furthermore, certain regions consist of intricate networks of alleys, present on both the Myanmar and Thailand sides of villages. These alleys pose challenges for inspection efforts due to the complexities associated with legal restrictions and jurisdictional boundaries.

Among the route results that do not correspond with the natural border path data, several areas stand out. These areas include Ban Ja Kae, Ban Via Kadi, the southern region of Ban Mai Phatthana, Lin Thin Subdistrict, Ban Thung Ma Se Yo, and Ban Tha Kham Sud. Despite not aligning with the information from Kanchanaburi Immigration, it is notable that the border area to the south of Ban Mai Pattana, Ban Thungmaseryoh, and Ban Tha Kham Sud can be traversed on foot. These regions have been frequently reported in the news, detailing instances of Burmese individuals seeking refuge and hiding along the border. Moreover, upon closer examination of the topography along the Kanchanaburi border, it becomes evident that while much of the region is characterized by rugged and elevated terrain, there are notable exceptions. Specifically, the stretch of land along the road that passes through the Ban Ja Kae border area presents a relatively flat landscape adorned with lush greenery, making it conducive for foot travel and offering potential hiding spots. In the case of Ban Vaikadee, although it does not consist of entirely flat terrain, the route follows a mountain ridge and is near the high-risk area of Ban Phrachedi Sam Ong, further enhancing its appeal as a route for illicit activities. Lastly, in the Lin Thin Sub-district, the route traverses through terrain that is relatively low in elevation. Consequently, this area is considered significant for monitoring and surveillance, as it is regarded as a route that provides both convenience and suitability for foot travel.

5. Conclusion

The study highlights the complex relationship between Myanmar and Thailand, with a focus on border security and illegal immigration issues. The research outcomes have revealed that Tak Province exhibits a significantly higher density of illegal crossing routes compared to other provinces, with Mae Sot District standing out prominently in this regard. This heightened incidence of illegal border crossings can be primarily attributed to the geographical factors at play, along with its proximity to villages on both sides of the border. Additionally, the research results shed light on the areas that are less amenable to foot travel for illegal entry along the border, namely Ratchaburi and Phetchaburi provinces. These regions' mountainous terrain and lack of border communities make them less accessible and unsuitable for travel and illegal activities. These findings hold significant implications for policymakers and officials tasked with addressing illegal border activities and enhancing security in border regions. Such insights can inform the development of targeted strategies to address the specific challenges posed by illegal border crossings, ultimately contributing to more effective border security measures.

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