Acadlore Transactions on Geosciences
https://www.acadlore.com/journals/ATG

Negative Externalities of Railway Station on Environmental Sustainability: Evidence from Tripura, India

Stabak Roy, Saptarshi Mitra*

Department of Geography and Disaster Management, Tripura University, 799022 Suryamaninagar, India

* Correspondence: Saptarshi Mitra (saptarshigeotu2000@gmail.com)

Received: 06-23-2022 **Revised:** 07-28-2022 **Accepted:** 08-15-2022

Citation: S. Roy and S. Mitra, "Negative externalities of railway station on environmental sustainability: Evidence from Tripura, India," *Acadlore Trans. Geosci.*, vol. 1, no. 1, pp. 53-66, 2022. https://doi.org/10.56578/atg010107.

Abstract: The development of railways brings many positive externalities, such as the expansion of built environment, the growth of feeder roads, the rise of passenger mobility, and the creation of economic opportunities for locals. In the meantime, the railway transport system exerts some negative externalities on environmental sustainability, which intensifies climate change. This paper assesses the negative externalities of railway transport through the changing dynamics of the normalized difference vegetation index (NDVI) and fractional vegetation cover (FVC). The spatial regression model was calibrated to understand the degree of these externalities. In addition, a prediction model was constructed based on machine learning techniques like cellular automata and Markov chain. The study reveals that the development of railway stations in Tripura, India has significant negative externalities on the environment.

Keywords: Railway infrastructure; Railway transportation; Railway geography; Machine learning; Cellular automata-Markov chain

1. Introduction

Railway infrastructure is severely impacted by the intricate interactions that govern the relationship between climate and transportation [1, 2]. Climate change is now universally accepted to be a serious issue that affects not only on the environment but also global society and economies [3]. Climate change can have a significant influence on rail infrastructure [4]. Individual CO_2 emissions and per capita Gross Domestic Product (GDP) were determined to be causally linked [5]. The environmental effects of carbon dioxide are offset by forests [6]. The railway is the most environmentally beneficial form of transportation, yet during its early development, there was significant environmental damage.

Due to development activities, environmental deterioration has reached a concerning level in the last few decades [6]. The expansion of infrastructure, particularly the railway transportation system, is of great concern around the world [7]. The railway industry is the most significant transport sector in India [8]. Due to its physiographic features and environmental sustainability, the Northeast has seen little expansion of railway transportation [9]. Railway transportation has proven essential to spurring the economic development, socio-cultural interaction, industrial progress, and infrastructure development of this region [10-12].

In 2013, the people of Tripura demanded a broad-gauge line to accommodate the state's unabated growth and delivered a memo to the railway minister and the chairman of the railway board in Delhi [3]. As part of a Unigauge project, the Ministry of Railways Government initiated the conversion of meter gauge lines into broad gauges [13]. The Badarpur-Kumarghat-Agartala section (except Badarpur Railway Station) took over for "Mega Block" for gauge conversion on September 20, 2015. This project was completed in six months. After the Mega Block Project, Agartala was connected to the rest of the nation by broad gauge track without the need for a "Break-of-Bulk" point [14].

The Agartala-Sabroom Section's construction began in 2008 (under the National Project's RB L/No. 98/W-1/NL/NF/6 Dated 24.10.2008). The Agartala-Udaipur railway track, which is 42.96 kilometers long, has been used for passenger service from August 28, 2016. On March 31, 2017, the 9.24 km long Udaipur-Garjee railway route underwent a Commission for Railway Safety (CRS) examination (General Manager (Construction), 2018). During the final quarter of 2018, the Garjee-Belonia railway route, measuring approximately 23.325 kilometers, was built [15].

The railway line between Gargi and Belonia is opened by the prime minister, Mr. Narendra Modi [16, 17]. As part of the 113 km long Agartala-Sabroom railway project, about 400 crores were spent establishing the Garjee-Belonia railway line. As approved by the Ministry of Railways, Government of India, the project's overall cost is approximately 3407 crores. The main goal of this project is to establish a connection between Sabroom, the border town of Tripura, and its most southern region.

On February 9, 2019, the first passenger train arrived in the border town of Belonia. On July 1, 2019, the Commissioner of Railway Safety (CRS) inspected the recently built 36 km rail line between Belonia and Sabroom, which passes five railway stations: Belonia, Jolaibari, Thailik Twisa, Manu Bazar, and Sabroom [18]. On October 8, 2019, the first passenger train arrived in Sabroom [19]. Some negative externalities were left by the railway in this optimistic scenario.

Environmental degradation is a common occurrence due to development of railway transport in Tripura [20]. Many researchers [21-27] focused on the positive externalities of railway transportation, yet failed to highlight the negative externalities of railway transportation.

The main objective of the study is to find out the negative externalities of railways in environmental sustainability. It has been observed that railway transportation has significant negative externalities in this aspect. In Tripura, it has been discovered that the most environmentally friendly areas are sparsely populated, forested, and have less developed infrastructure. Papers have been structured to accurately convey the facts, including a detailed literature review, methodology, study area, empirical evidence, and conclusions.

2. Literature Review

Rail is usually viewed as the cleanest and most energy-efficient means of transportation, but Damián and Zamorano [28] pointed out that the emissions and energy use during construction are frequently ignored. For five alternative Rock Mass Rating (RMR) classes, the authors carried out a life cycle assessment (LCA) approach to determine the environmental impact of building a 1 km double-track high-speed railway tunnel.

According to Lin et al. [29] there is a significant correlation between employment, fixed asset investment, average wage, and higher education institutions and regional economic growth in China. In contrast to employment, fixed asset investments, and average salary rates, higher education institutions have a negative impact on regional economic growth. The data show that the quality of higher education has a significant impact on China's regional economy.

To better understand and capture stakeholder perceptions, Nyumba, et al. [30] studied the interactions between the Standard Gauge Railway (SGR) and the crossed natural systems in Kenya through qualitative content analysis. The three key themes that arose were deterioration, fragmentation, and ecosystem destruction. Ecosystem destruction was less of a concern and primarily restricted to the actual SGR development, whereas degradation and fragmentation have a far wider reach. Ecosystem degradation was the most often reported effect.

Lucas et al. [31] evaluated how much disruption railroads cause due to noise and vibration, soil erosion, air, water, and ground contamination. There is evidence that hydrological and soil contamination may affect plants, aquatic life, and terrestrial life. It was observed that the presence of railroads makes predators avoid the area and lowers the diversity and abundance of some invertebrates, amphibians, and birds. It is interesting to note that animals like reptiles, some bird species, small mammals, and large mammals seem to ignore train traffic and benefit from the food- and shelter-giving vegetation that has adapted to the railway verges. Engineering structures like rail fastenings, rail dampers, and under-sleeper pads have been installed to lessen the effects of railway disruption.

Rodrigue et al. [32] explained that, when consumers have access to free or cheap transportation infrastructure, congestion frequently develops as an unanticipated side effect. However, as infrastructure and capacity struggle to keep up with the rising transportation needs, congestion is also an indication of an expanding economy. Transportation carries a nonnegligible social and environmental burden.

According to Dionelis and Giaoutzi [33] specifically in the context of trans-European networks, environmental protection criteria have been incorporated into the design and implementation of Community transportation policy. As one of the safest ways of transportation, this necessitates prioritizing the promotion of rail infrastructure. The European Transport Policy as a whole has long placed a priority on environmental and safety rules.

Plakhotnik et al. [34] focused their examination of the ecological situation in Ukrainian railway transportation on the Prydniprovs'ka regional railways. There is a considerable contamination found. The various environmental effects of railway subdivisions were compared, and a computer simulation was carried out to compare data.

Debrezion et al. [35] found that the physical, accessible, and environmental features of a property affect its value. Railway stations are places in cities and function as transportation system hubs. It is simple to access them, and environmental factors influence how much a property is worth. The literature on the effects of railroad stations on property value is contradictory in terms of influence magnitude and direction, with results ranging from a detrimental to a negligible or beneficial effect of railway growth.

3. Methodology

Some negative externalities have occurred as a result of the development of the rail transportation system. In 2016, the railway transportation system in India underwent a significant overhaul. To understand the negative externalities of the growing railway transportation on the environment, Mohammad et al. [36] processed and analyzed Sentinel-2 satellite images with the normalized difference vegetation index (NDVI). The NDVI can be calculated by dividing the total of the red (Band-4) and infrared (Band-8) reflected light intensity by the difference between the two intensities:

$$NDVI = \frac{B8(VNIR) - B4(\mathrm{Re}\,d)}{B8(VNIR) + B4(\mathrm{Re}\,d)},$$

where, B8 is the visible and near infrared band with 10 m resolution and 842 nm central wavelength; B4 is the red band with 10 m resolution and 665 nm central wavelength. The NDVI of a railway station and its surroundings indicate the density of forest (canopy), and urban and water features. Using the fractional vegetation cover (FVC), the loose canopy density can be determined by the linear unmixing model:

$$NDVI = f \times NDVI_v + (1+f) \times NDVI_s$$

Then,

$$f = \frac{NDVI_i - NDVI_s}{NDVI_v - NDVI_s}$$

Where,

$NDVI_i$ is the NDVI of the mixed pixel of i^{th} railway station,

$NDVI_v$ is the NDVI of the fully covered vegetation,

$NDVI_s$ is the NDVI of bare soil

where, $NDVI_i$, $NDVIv$, and $NDVI_s$ are the NDVIs of the mixed pixel of the i-th railway station, the fully covered vegetation, and bare soil, respectively.

Exponential smoothing can be utilized to forecast the degradation of vegetation cover in the surroundings (3km radius) of the railway station. The exponentially smoothed average for time t (u_t) is the weighted average of observations y_t, y_{t-1}, y_{t-2}, …. The weights of the observations are w_t, w_{t-1}, w_{t-2}, …, respectively, which satisfy $w_t + w_{t-1} + w_{t-2}, \ldots = 1$. Thus, u_t can be defined as:

$$\begin{aligned} u_t &= \frac{w_t y_t + w_{t-1} y_{t-1} + w_{t-2} y_{t-2} + \ldots}{w_t + w_{t-1} + w_{t-2} + \ldots} \\ &= w_t y_t + w_{t-1} y_{t-1} + w_{t-2} y_{t-2} + \ldots, \\ &= \alpha y_t + \alpha(1-\alpha) y_{t-1} + \alpha(1-\alpha)^2 y_{t-2} + \ldots, \end{aligned}$$

where, $w_{t-\partial} = \alpha(1-\alpha)^{\partial}$, $\partial = 0; 1; 2; \ldots$.

Markov chain is another stochastic method for detecting and forecasting vegetation change. Mitra et al. [37] calibrated this approach on the TerrSet 2020 software. Let x_1, x_2, x_3, x_4 and x_{15} be the different classes of NDVI, respectively, in 2022. Then, we have:

$$p_{ij} = \text{The probability of changing the } i^{th} \text{ class NDVI pattern (in period } t\text{) into } j^{th} \text{ class NDVI from } t_1 \text{ to } t_2$$

where, t_1=2019, t_2=2022.

The probability for the i-th class of NDVI in period t to change into the j-th class from t_1 to t_2.

$$A = \begin{pmatrix} p_{11} & p_{12} & p_{13} & p_{14} & p_{15} \\ p_{21} & p_{22} & p_{23} & p_{24} & p_{25} \\ p_{31} & p_{32} & p_{33} & p_{34} & p_{35} \\ p_{41} & p_{42} & p_{43} & p_{44} & p_{45} \\ p_{51} & p_{52} & p_{53} & p_{54} & p_{55} \end{pmatrix}_{5\times5} = Stochastic\ Matrix$$

Then,

$$B=\begin{pmatrix} b_{11} \\ b_{21} \\ b_{31} \\ b_{41} \\ b_{51} \end{pmatrix}_{5\times 1} = \text{Re presents the matrix whose elements } b_{i1}$$

$$b_{i1} = \text{proportion of NDVI under } i^{th} \text{category} = \frac{x_i}{N}$$

$$N = \text{Total NDVI in period } t_2$$

Re is the matrix with elements b_{i1}.
Note that b_{i1} is the proportion of NDVI in the i-th class=x_i/N, with N being the total NDVI in period t_2.
Then,

$$\left.\begin{array}{l} AB \text{ will be on } 5\times 1 \text{ matrix whose elements will represent the} \\ \text{proportion of land under ith category in the year 2025} \end{array}\right\}\text{......................for 2025} \quad (1)$$

$$\left.\begin{array}{l} A^2B \text{ will represent the proportion of land under } i^{th} \text{ category} \\ \text{in the year 2028} \end{array}\right\}\text{...................... for 2028} \quad (2)$$

Then, we have:
For 2025,
AB will be on a 5×1 matrix, whose elements represent the proportion of land under the i-th class in 2025.
For 2028
A^2B will represent the the proportion of land under the i-th class in 2028.
The software TerrSet v. 2020 was adopted to graphical represent the predictive NDVI of the surroundings of the target railway stations in 2024 and 2027.

4. Study Area

The study was carried out in Tripura, an Indian state in the northeast with a 10,486 km^2 total land area. Only 0.31 percent of India's entire geographic land area is held by the state. Tripura is a landlocked state bordered by Bangladesh to the north, south, and west (856 km), Indian state Assam to the northeast (53 km), and Mizoram to the east (109 km) [8].

Geographically speaking, the state is a part of Purvanchal (Eastern Mountains), and the entire area is characterized by a low-lying plain that is intersected by a number of low-drawn hillocks beginning with the Mizo hills. Tripura is a very hilly state with topography that includes valleys and ridges (Tilla and Lunga) [8, 38]. The piedmont-style plains of Tripura are situated at the foot of the north-to-south oriented hill ranges that extend from the Mizoram state. North-South linear anticlinal hill ranges and related valleys make up the state's physiography [39]. Of its total area, about 60% is hilly and the remaining 40% is plain. Even the plains are not completely level; rather, they are broken up by several little hills and tillas that rise 30 to 60 meters above sea level and are covered in trees and bushes [38].

Six anticlinal hill ranges can be found in the state: The Baramura, Atharamura, Longtharai, Shakhan, Jampui, and Deotamura ranges. The Longtharai (515 m), Atharamura (481 m), and Baramura (249 m) major hills are traversed by the railway track from north to south [29]. From the hills came many rivers, small streams, gullies, and ravines. From north to south, the state has 11 major rivers: Longai (98 km), Juri (98 km), Deo (98 km), Manu (167 km), Dhalai (117 km), Khowai (70 km), Haora (53 km), Bijoy (26 km), Gomati (64 km), and Feni (Figure 1). Those streams eroded the hill ranges as they cross through the valleys in between. The eroded materials spread over the western part of the state. This western portion is part of the Ganga-Brahmaputra lowlands and belongs to the lower flood plain area of the Ganga-Brahmaputra-Meghna (GBM) river system.

According to Koppen's categorization of climate, this state most strongly resembles a tropical Savannah climate (Aw). Tripura is located along the Tropic of Cancer. This region often experiences the seasons of summer, rainy season, autumn, and winter. In addition, June is noted as being significantly hotter as climatic conditions change [40]. In these months, the average maximum temperature ranged from 24°C to 36°C. The winter months are typically dry and between 13 and 26°C. Heavy rains brought on by the monsoonal winds eventually result in regular floods. In the state, the total yearly rainfall ranges from 1,500 mm to 2,500 mm. The rainy season normally lasts from June to September. Because of the region's steep terrain and frequent landslides during the monsoon, Tripura's roadways are in very poor shape [41]. In this situation, the railway becomes Tripura's primary means of transportation [21].

Between Churaibari Railway Station (24°26′ N. and 92°14′ E.) in the north to Sabroom (23°0′ N. and 91°42′ E.) in the south, there are 25 intermediate stations along the approximately 264 km long operable railway track of the Indian state of Tripura, the study area. The railway stations are as follows: Nadiapur (24˚23′ N. and 92˚12′ E.), Dharmanagar (24˚22′ N. and 92˚10′ E.), Panisagar (24˚16′ N. and 92˚09′ E.), Pecharthal (24˚11′ N. and 92˚06′ E.), Kumarghat (24˚09′ N. and 92˚02′ E.), Nalkata (24˚03′ N. and 92˚00′ E.), Manu (23˚59′ N. and 91˚59′ E.), S.K. Para (23˚58′ N. and 91˚58′ E.), Jawaharnagar (23˚55′ N. and 91˚54′ E.), Ambassa (23˚55′ N. and 91˚51′ E.), Mungiakami (23˚53′ N. and 91˚42′ E.), Teliamura (23˚51′ N. and 91˚37′ E.), Jirania (23˚49′ N. and 91˚25′ E.), Jogendranagar (23˚48′N. and 91˚18′E.), Agartala (23˚47′N. and 91˚16′E.), Sekerkote (23°44' N. and 91°16'E.), Bishalgarh (23°40' N. and 91°16' E.), Bishramganj (23°35' N. and 91°21' E.), Udaipur (23°30' N and 91°28' E.), Garjee (23°25' N, and 91°29' E.), Santirbazar.(23°19' N. and 91°31' E.) Belonia (23°14' N. and 91°29' E.), Jolaibari (23°11' N. and 91°35' E.), Thailik Twisa (23°7' N. and 91°36' E.) and Manu Bazar (23° 3' N. and 91°38' E.).

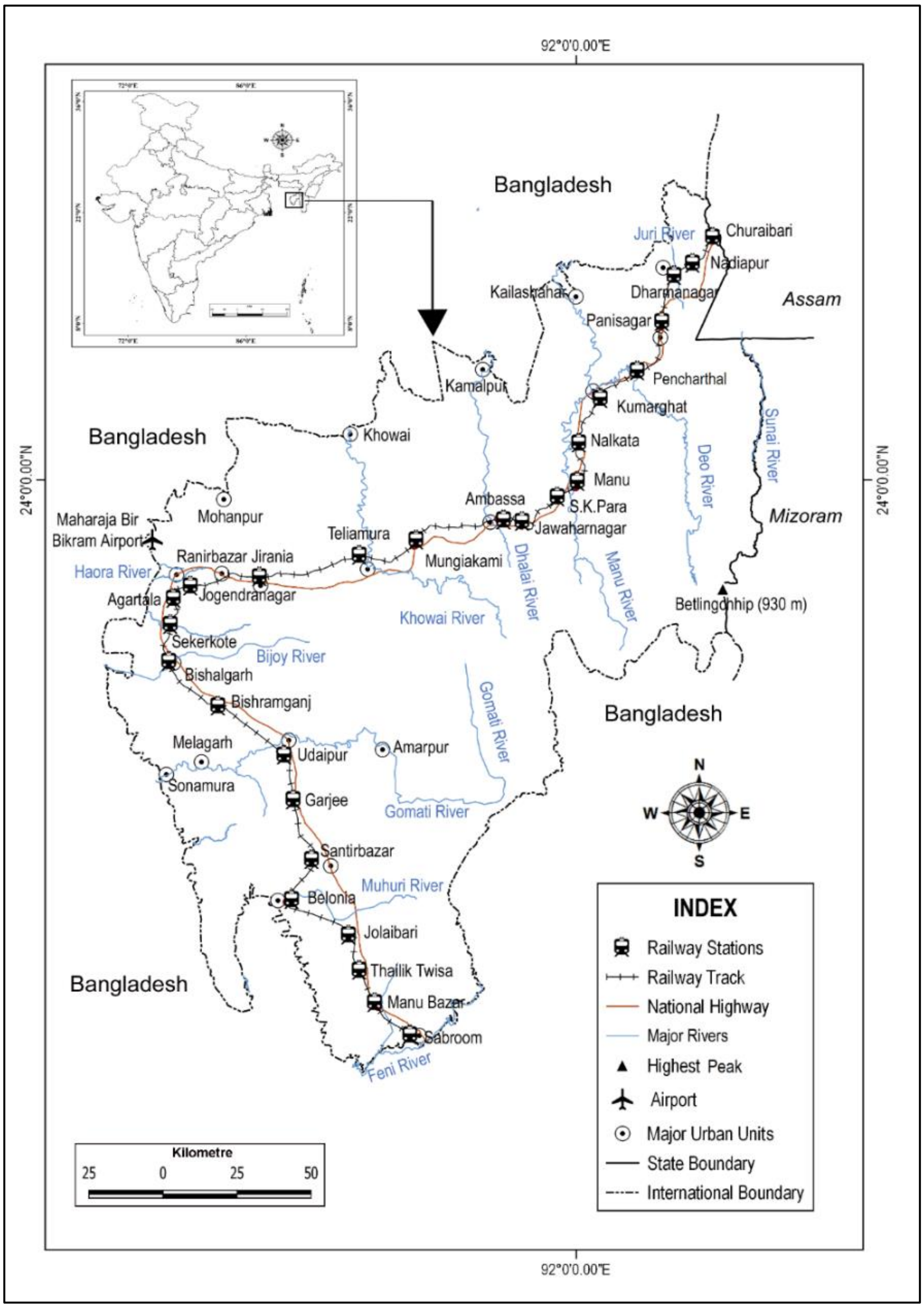

Figure 1. Location map of the study area
(Source: Prepared by the authors, 2022)

5. Empirical Evidence

It has been observed that in 2016 NDVI was higher in Thailik Twisa (0.63708) and Nadiapur (0.52877). In 2016, the average NDVI value was 0.15872 with a standard deviation of 0.12559. Both the stations are located in rural areas; as a result, agricultural practices and rubber cultivation is the predominating activities. NDVI of 77.78 per cent (21 out of 27) railway stations, namely Agartala, Manu Bazar, Jirania, Santirbazar, Garjee, Teliamura, Manu, Jolaibari, Ambassa, Bishalgarh, Udaipur, Sekerkote, Belonia, Jawaharnagar, Sabroom, Jogendranagar, Panisagar, Dharmanagar, Mungiakami and Churaibari of Tripura is below the average. Poor NDVI values were found in Agartala railway stations (0.0389771) and other stations located in Urban and peri-urban areas like Manu Bazar (0.08719), Jirania (0.09414), Santirbazar (0.09652), Garjee (0.09674) and Teliamura (0.10274) railway station surrounding area have the poor concentration of vegetation is surrounded by the railway stations (Figure 2). It has been observed that where vegetation index is high, passenger mobility is less. The vegetation index has vegetation relation with passenger mobility. On the way, it may say that if passenger mobility is increased, vegetation cover will be reduced due to developmental activities. Maximum railway stations were developed or renovated after 2016 during gauge conversation (meter gauge to broad gauge).

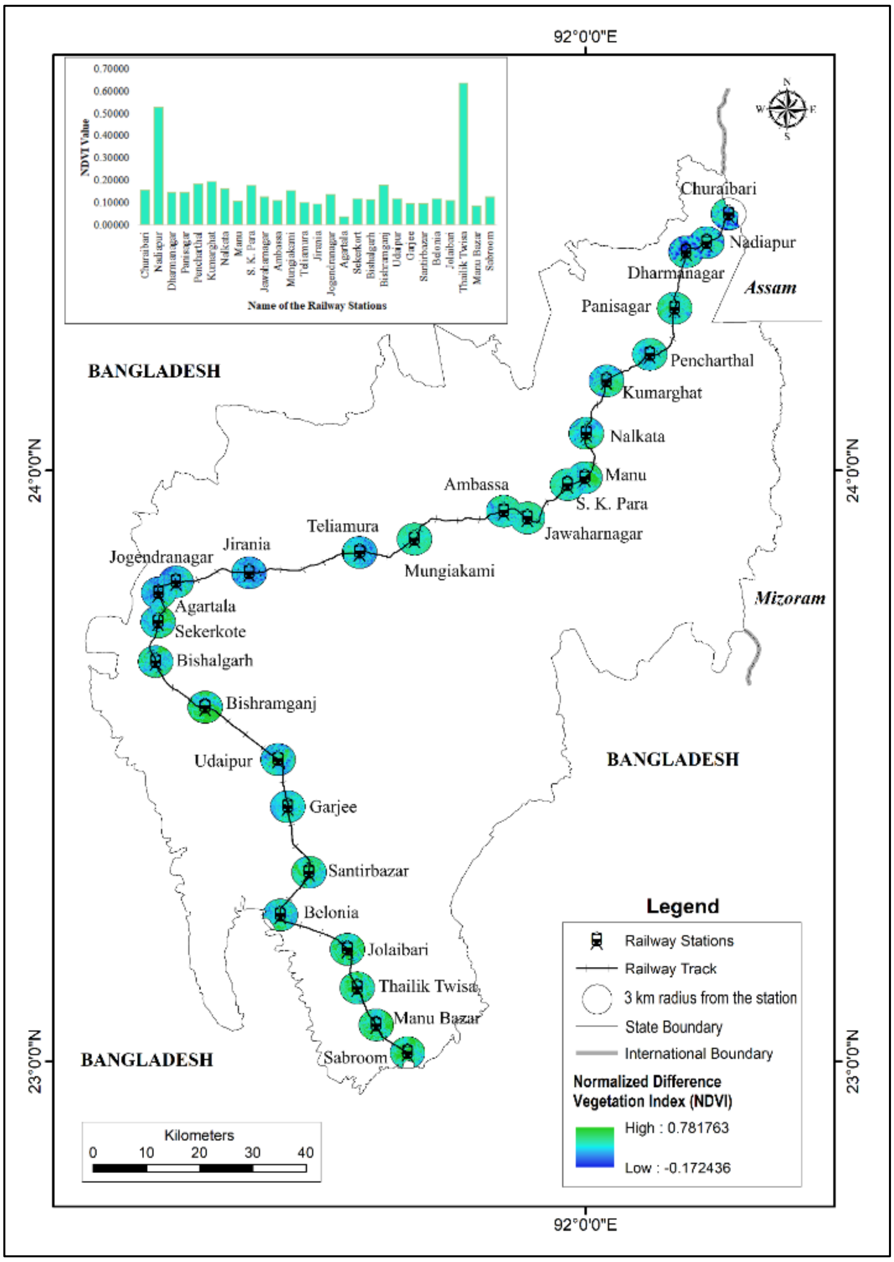

Figure 2. NDVI of railway stations surrounding area of Tripura in 2016
(Source: Prepared by the authors, 2022)

Table 1. Externalities of railway stations on environment

Name of the Railway Stations	NDVI in 2016	NDVI in 2019	NDVI in 2022	Predictive NDVI of 2025
Churaibari	0.15746	0.06172	0.06062	-0.00003
Nadiapur	0.52877	0.10037	0.09949	-0.17039
Dharmanagar	0.14847	0.06551	0.05979	0.00547
Panisagar	0.14772	0.10574	0.09678	0.06704
Pencharthal	0.18438	0.15623	0.14327	0.12075
Kumarghat	0.19402	0.13044	0.11411	0.06805
Nalkata	0.16347	0.16025	0.15157	0.14633
Manu	0.10904	0.10295	0.08763	0.07811
S. K. Para	0.17817	0.17554	0.17262	0.06988
Jawaharnagar	0.12697	0.09811	0.06086	0.02775
Ambassa	0.11118	0.11020	0.10782	0.10632
Mungiakami	0.15409	0.08435	0.08130	0.03628
Teliamura	0.10274	0.10215	0.10200	0.10158
Jirania	0.09414	0.09324	0.09122	0.08990
Jogendranagar	0.13789	0.11136	0.10500	0.08595
Agartala	0.03898	0.03731	0.03011	0.02639
Sekerkote	0.11748	0.11221	0.11066	0.10677
Bishalgarh	0.11423	0.11261	0.10105	0.09574
Bishramganj	0.18311	0.09465	0.09305	0.03680
Udaipur	0.11707	0.11426	0.08420	0.07129
Garjee	0.09674	0.09140	0.09109	0.08762
Santirbazar	0.09652	0.08709	0.08175	0.07384
Belonia	0.11813	0.04784	0.04711	0.00261
Jolaibari	0.11066	0.10346	0.10088	0.09538
Thailik Twisa	0.63708	0.06053	0.05539	-0.30929
Manu Bazar	0.08719	0.08354	0.08326	0.08085
Sabroom	0.12963	0.06643	0.05480	0.01073

Source: Computed by the authors, 2022

Negative externalities have taken place after the rapid development of railway infrastructure since 2016. It has been observed that all the railway stations surrounding the area of Tripura reported negative growth of NDVI (Table 1).

It is observed that in 2019, S. K. Para (0.17554), Nalkata (0.16025), Pencharthal (0.15623) railway stations had comparatively better environmental conditions (Table 1). Whereas in the same year, Agartala railway station (0.03731) had a very poor condition of green infrastructure. Rapid urbanisation and related activities around Agartala railway station resulted in a poor level of NDVI (Table 1). The second poor green infrastructure was found in Belonia railway station (0.04784). The present location of Belonia railway station was a forested area before 2018. During 2018 huge changes in land use pattern took place in and around Belonia railway station as a poor NDVI value has been reflected in the images of 2019 (Figure 3). Belonia is the district headquarter of south Tripura District and a significant number of passengers moves from this station, so the Government put special emphasis in this railway station. Tripura District and a significant number of passengers moves from this station, so the Government put special emphasis in this railway station.

Belonia town is located about 3 km from Belonia railway station due international boundary vulnerability of Belonia town is high [42]. The growth pole of Belonia town gradually shifted towards Belonia railway station due to comparatively less vulnerability. A similar kind of result was found at Thailik Twisa railway station (23°07'28"N. and 91°36'50"E.) as well as the surrounding area. Thailik Twisa is a small tribal concentrated area of Kali Bazar ADC Village (23°06'50"N. and 91°35'56"E.) under Satchand Rural Development Block in South Tripura District, Tripura.

Physiographically, Thailik Twisa is located between Betaga knoll and the Deotamura hill range,a small streamlet called 'Kalachara' flows through this area. Geographically, Thailik Twisa station is located about 97 km from the capital city Agartala and about 22 km south of Belonia, the District Headquarters. A few years ago, this area was covered by forest, which gradually has been converted into a rubber garden. Rapid transportation has taken place after the introduction of railways in this area. As per Figure 4, In 2006 rubber plantation was started in this area where the present Thailik Twisa Railway Station is situated. Gradually, the plantation area has been expanded till 2014 (Figure 4). In order to develop the railway line, initial activities were started by the railway authority in 2015. But at that time, no mark of the station was found there (Figure 4). Constructional work for developing the Thailik Twisa railway station was started in the last quarter of 2018. In October 2019 the station became operational (Figure 5).

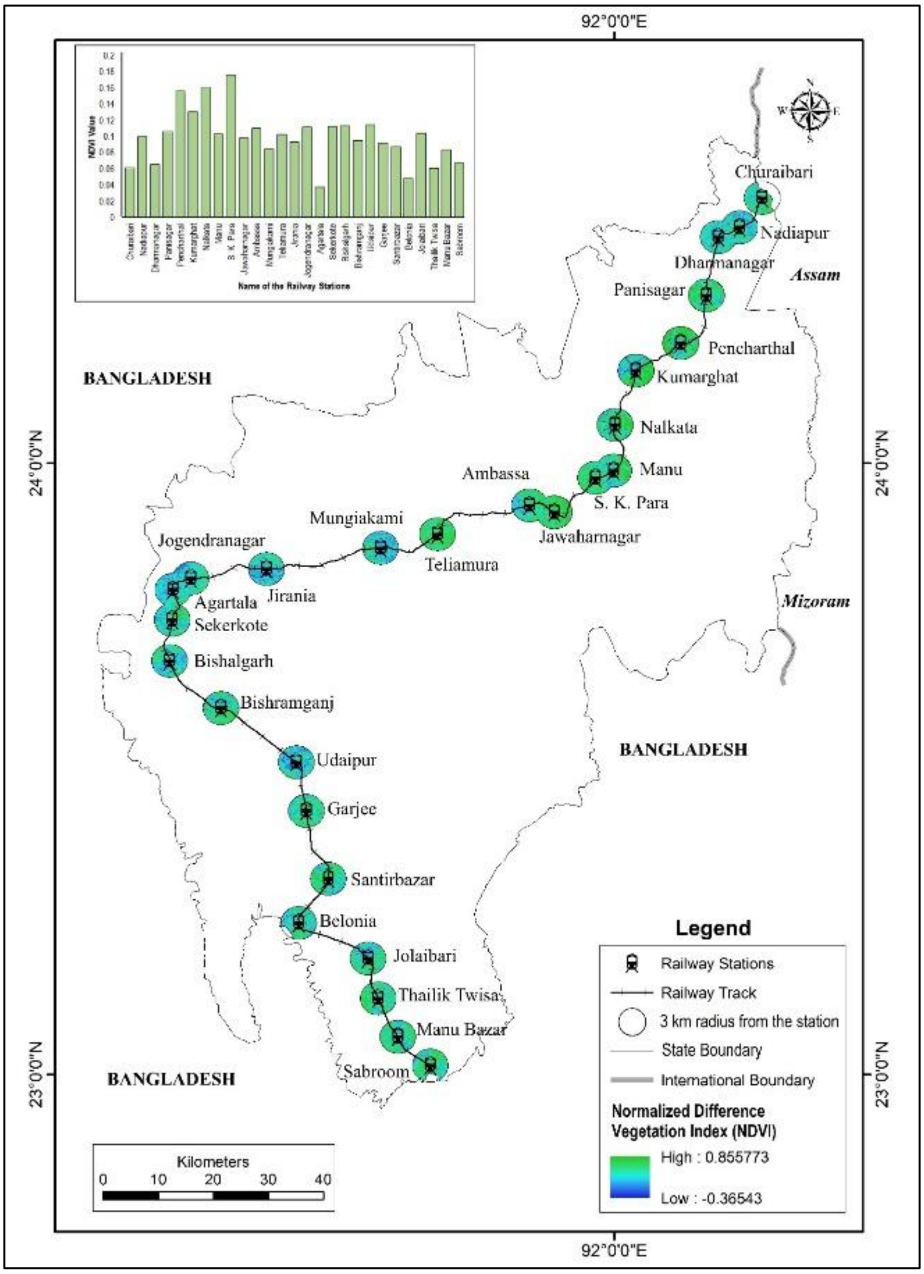

Figure 3. NDVI of railway stations surrounding area of Tripura in 2019
(Source: Prepared by the authors, 2022)

Not much difference has been found in the NDVI data for 2019 and 2022. The reasons behind less environmental degradation took place due COVID-19 pandemic-related lockdown. Good environmental conditions were found in S. K. Para (0.17817), Nalkata (0.16347), Pencharthal (0.18438), Kumarghat (0.19402) and Sekerkote (0.11748). Expect Kumarghat railway station remaining top four environmentally rich railway stations are located in the forested area of Tripura (Fig. 6.33). In antipodes, Agartala (0.03011), Belonia (0.04711), Sabroom (0.0548), Thailik Twisa (0.05539) and Dharmanagar (0.05979) railway stations have very poor environmental conditions in terms of NDVI. It has been observed that among the five (5) worst environmental stations of Tripura, 80 per cent are located in the urban area except for Thailik Twisa railway stations. In 2019, the Oil and Natural Gas Corporation (ONGC) set up the Gojalia Gas Collecting Center (GCS), which was established about 200 m away from Thailik Twisa railway station. Externalities of railways put extra value on this Gas Collecting Center. Eklavya Model Residential School (EMRS), a senior secondary school in Thailik Twisa is located about 850 m away from the railway station. The main objective of Eklavya Model Residential School is to educate students of scheduled tribes. The externalities of Thailik Twisa railway station help the movement of students and teachers of Eklavya Model Residential School easily. Presently this station influences the land use pattern of Bhuratali, Dakhsin Kalapania, Fulchhari, Gaganchandra Para, Gardhang, Uttar Kalapania, Sindukpathar Sakbari etc., areas located within a three km radius [42]. All 11 railway stations in the southern part of Tripura (Agartala-Sabroom Section) reflected the more negative environmental externalities between 2016 and 2022. Newly developed infrastructure in the southern section is the main reason for more negative environmental externalities because earlier, those areas were reported as forested land and converted into built-up area within a short span of time. It asserts that urbanised railway stations of Tripura have suffered from more negative environmental externalities.

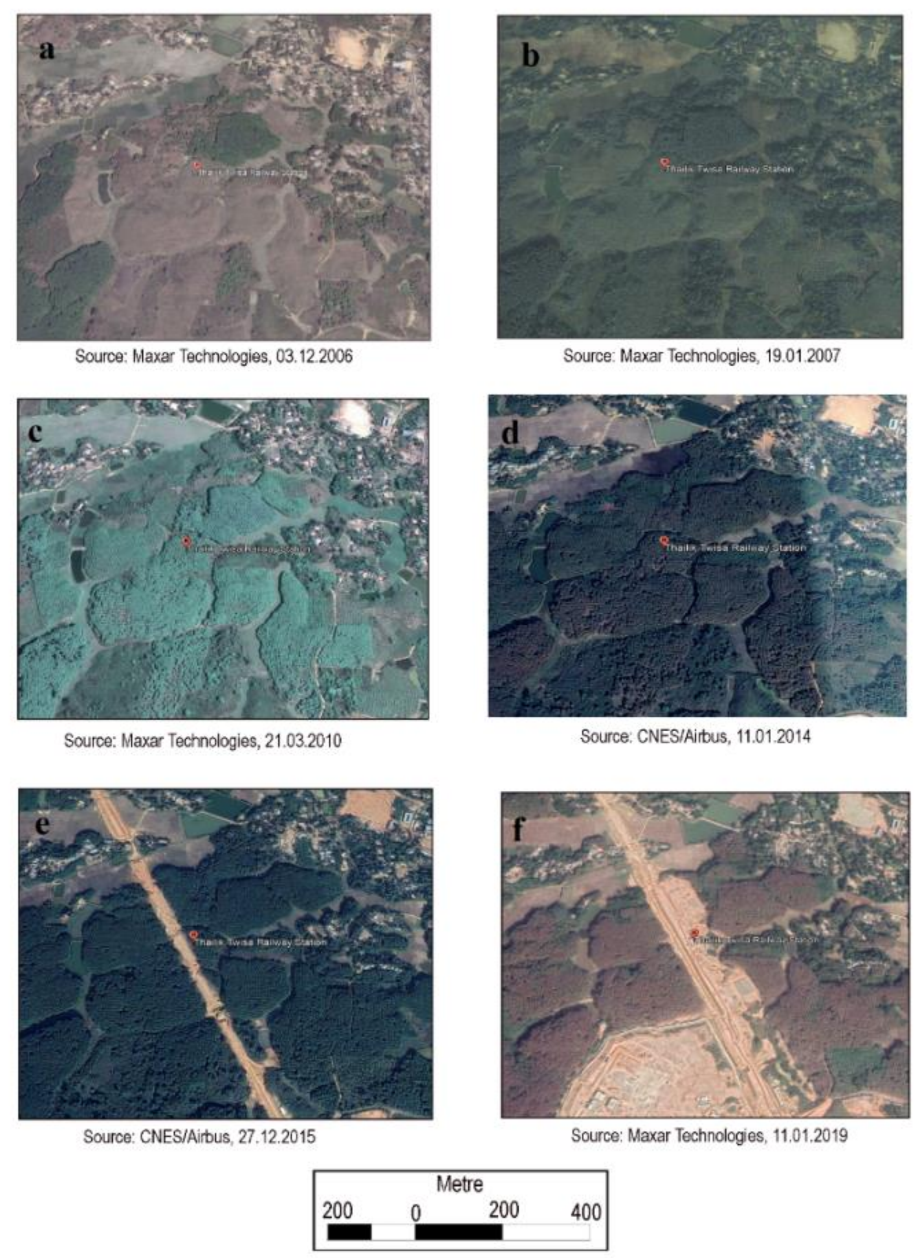

Figure 4. NDVI of railway stations surrounding area of Tripura in 2019
(Source: Roy et al., 2022)

From the predictive model, it has been observed that Nalkata, Pencharthal and Sekerkote railway stations will hold the top position in terms of environmental sustainability. But more vulnerability will be found in Thailik Twisa railway station as Thailik Twisa have huge growth potentiality [42]. Thailik Twisa railway station has some Strengths, Challenges, Opportunities and Threats (SCOT). As per the study, Thailik Twisa railway station has some strengths like a huge hinterland for passenger traffic, close proximity with National Highway 8 and Kalachara Market and well connectivity with nearby settlements, etc. (Table 2). This station is suffering from a few weaknesses like only one platform and single-track railway network, less frequent train service (8 trains per day), inoperative infrastructural setups like ticket counters, public addressing system, sanitation facility, etc. (Table 2).

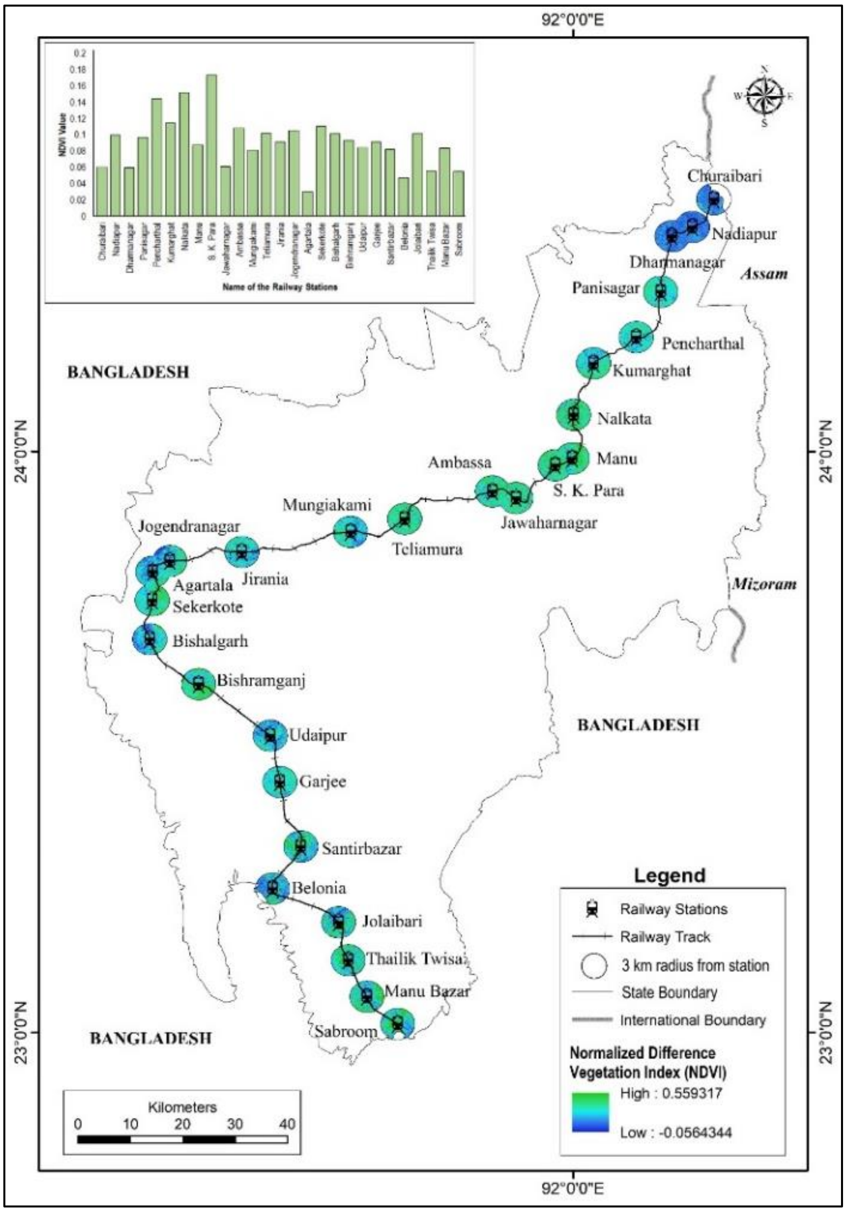

Figure 5. NDVI of railway stations surrounding area of Tripura in 2019
(Source: Prepared by the authors, 2022)

Table 2. SCOT Analysis of Thailik Twisa Railway Station, Tripura

	Internal Factors		
	Strengths	Challenges	
Positive Factors	Huge hinterland for passenger traffic with 600-650 passengers (approx.). Close proximity with National Highway 8 and Kalachara Market which nodal business hub and epicentre of road transportation. Better connectivity with nearby settlements	Only one platform and single-track railway track, Less frequent train service (8 per day), Inoperative infrastructural set ups like ticket counters, public addressing system, sanitation facility, waiting room etc.	Challenging Factors
	External Factors		
	Opportunities	Threats	
	This station has huge potentiality in tribal area development through import and export of goods, Future development is highly associated with gradual growth of Gojalia Gas Collecting Center (GCS) of ONGC which is located only 200 meters away from the station.	Frequent bus service from Kalachara Market to Agartala and adjoining parts of South Tripura District, Increasing road traffic (10-12 bus for Agartala), High performing National Highway (NH-8).	

Source: Computed by the researcher, 2019-2021

Apart from these internal factors, many external factors like frequent bus service from Kalachara Market, increasing road traffic, and close proximity of high-performing national highways are simultaneously the opportunity and threat of the growth of railway transportation from Thailik Twisa railway station (Table 2). Simultaneously like this station has huge potentiality in tribal area development through the mobility of passengers and goods and future development is highly associated with the gradual growth of the Gojalia Gas Collecting Station (GCS) of ONGC, which is located only 200 meters away from the station. All those reasons may be responsible for the negative spatial externality of Thailik Twisa railway station. Churaibari and Nadiapur will also have growth potential due to locational advantage as those two stations are located adjacent to the Assam border, resulting from negative environmental externalities. To measure loose canopy density analysed through Fractional vegetation cover (FVC).

It has been observed that during 2016, maximum canopy density loss occurred in Thailik Twisa railway station, followed by Nadiapur railway station (Figure 6). S. K. Para reported maximum canopy density loss during both 2019 and 2022, respectively. Figure 6 depicts that the fractional vegetation cover of Agartala railway station is static. The infrastructure development of Agartala railway station started in 2008, and the growth process is almost stagnant, which is the reason for the static decline of the fractional vegetation cover of Agartala railway station.

CA-Markov chain has been used to calibrate the predictive model. As per the predictive model concern, every NDVI value will decrease significantly, but the decay rate will be slower than in the previous assessment period (Figure 7).

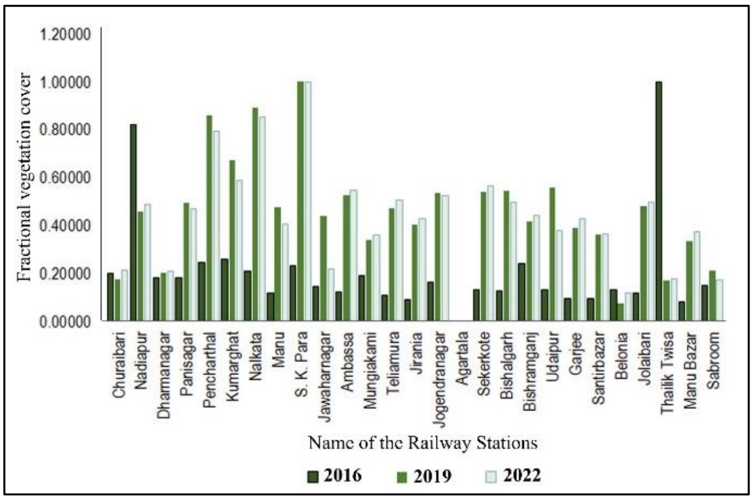

Figure 6. Fractional vegetation cover during 2016, 2019 and 2022
(Source: Prepared by the authors, 2022)

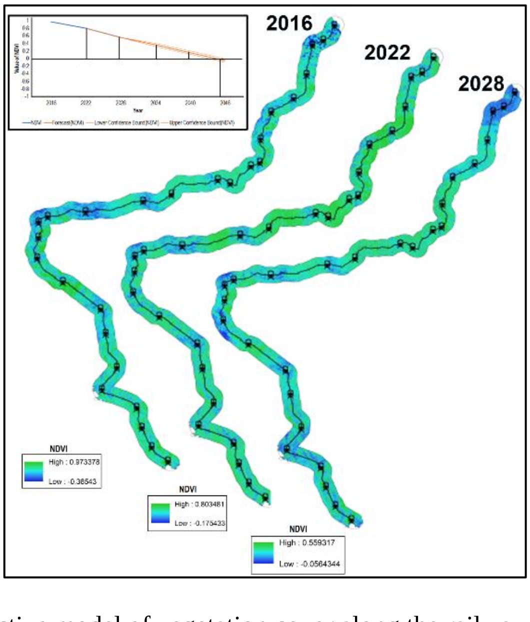

Figure 7. Predictive model of vegetation cover along the railway track in Tripura
(Source: Prepared by the authors, 2022)

6. Conclusions

The development of railway transport system has strong negative externalities on environmental sustainability. The rate of environmental decay is much higher in the initial years of development; subsequently, it reduces. Externalities of railway development on the environment are a common concern. There are various technical strategies to maintain environmental sustainability within railway premises. Green corridors and green stations are the best practical solution to reduce the level of the negative externality of railway stations on the environment. India currently has five green railway corridors and seven green stations, but no one is located in Tripura, even in Northeast India. By introducing the green railway corridors and green stations model, negative externalities on the environment could be reduced. Railway transport system has immense value in economic growth and regional development. However, every positive changes have some negative notes. Which mostly ignored in the developmental geography. Environmental policy on railway development generally absents in developing countries. For micro-level regional planning, it is required to understand small scale environmental impact of railway transport system. Centralized policy not feasibility for large country like India as climate, physiography, developmental process, economic growth and man-environment relationship is varied region to region. To address micro level regional sustainability decentralized policy framework, need to developed.

Author Contributions

"Conceptualization, S. R. and S. M.; methodology, S.R.; software, S.R.; validation, S.M.; formal analysis, S.R.; resources, S.M.; data curation, S.R.; writing—original draft preparation, S.R.; writing—review and editing, S.R and S.M.; visualization, S.R.; supervision, S.M. All authors have read and agreed to the published version of the manuscript."

Data Availability

The data [multispectral spatial data] supporting our research results are included within the article or supplementary material.

Acknowledgements

Authors are thankful to Area Manager, Badarpur and the station masters of all the railway stations of Tripura.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] R. Talchabhadel and R. Karki, "Assessing climate boundary shifting under climate change scenarios across Nepal," *Environ Monit. Assess.*, vol. 191, Article ID: 520, 2019. https://doi.org/10.1007/s10661-019-7644-4.

[2] W. Rothengatter, Y. Hayashi, K. Fujisaki, H. Kato, T. Okuda, and N. Shibahara, "Climate change impacts of intercity transport in the context of external costs and their internalisation," *In Intercity Transport and Climate Change: Transportation Research, Economics and Policy*, Y. Hayashi, S. Morichi, T. Oum, and W. Rothengatter (Eds.), Chem: Springer, pp. 85-169, 2015. https://doi.org/10.1007/978-3-319-06523-6_3.

[3] E. A. Kostianaia, A. G. Kostianoy, M. A. Scheglov, A. I. Karelov, and A. S. Vasileisky, "Impact of regional climate change on the infrastructure and operability of railway transport," *Transp. Telecommun. J.*, vol. 22, no. 2, pp. 183-195, 2021. https://doi.org/10.2478/ttj-2021-0014.

[4] E. J. Palin, I. S. Oslakovic, K. Gavin, and A. Quinn, "Implications of climate change for railway infrastructure," *WIREs Clim. Change*, vol. 12, no. 5, pp. 2-41, 2021. https://doi.org/10.1002/wcc.728.

[5] V. A. Profillidis, G. N. Botzoris, and A. T. Galanis, "Environmental effects and externalities from the transport sectorand sustainable transportation planning – a review," *Int J. Energy Econ. Policy*, vol. 4, no. 4, pp. 647-661, 2014.

[6] Z. Li, Z. Mighri, S. Sarwar, and C. Wei, "Effects of forestry on carbon emissions in China: Evidence from a dynamic spatial Durbin model," *Front Environ Sci*., vol. 9, Article ID: 760675, 2021. https://doi.org/10.3389/fenvs.2021.760675.

[7] M. B. Bouraima, Y. Qiu, B. Yusupov, and C. M. Ndjegwes, "A study on the development strategy of the railway transportation system in the West African Economic and Monetary Union (WAEMU) based on the SWOT/AHP technique," *Sci. Afr.*, vol. 8, Article ID: e00388, 2020. https://doi.org/10.1016/j.sciaf.2020.e00388.

[8] S. Roy and S. Mitra, *Intra State Mobility Pattern of Railway Passengers in Tripura, India*, Guwahati, India: Suprava Publication, pp. 70-92, 2018.
[9] S. Roy and S. Mitra, "Infrastructural status of railway transport system in north east India: A geographical analysis," *Asian J. Spat. Sci*., vol. 4, no. 1, pp. 89-100, 2016.
[10] A. K. Choudhary and S. Rao, "History of rail transportation and importance of Indian Railways (IR) transportation," *Int J. Eng. Dev. Res*., vol. 6, no. 3, pp. 73-77, 2018.
[11] O. Skorobogatova and I. K. Merlino, "Transport infrastructure development performance," *Procedia Eng*., vol. 178, pp. 319-329, 2017.
[12] "Infrastructure lessons for economic growth and business success," Ginovus, 2012.
[13] "The Press Trust of India," India TV, 2020, https://www.indiatvnews.com/news/india-indian-railways-begin-service-in-tripura-agartala-sabroom-line-bangladesh-border-531966.
[14] "Mega Block in Badarpur-Kumarghat-Agartala Section," North East Frontier Railway, 2015, https://nfr.indianrailways.gov.in/view_detail.jsp?lang=0&dcd=855&id=0,4,268.
[15] "Indian Railways connects remote parts of North-East with inauguration of GarjeeBelonia line in Tripura," Financial Express, 2019, https://www.financialexpress.com/infrastructure/indian-railways-garjee-belonia-railway-line-narendra-modi-tripura/1483006/.
[16] "PM Modi lays foundation stone and inaugurates development projects at Agartala, Tripura," Modi, Agartala, Tripura, 2020, https://www.narendramodi.in/pm-modi-lays-foundation-stone-and-inaugurates-development-projects-at-agartala-tripura-543443.
[17] "PM inaugurates Garjee-Belonia railway line in Agartala," Agartala, Tripura, India: Asian News International (ANI), 2020, https://www.youtube.com/watch?time_continue=67&v=X9av1U2Udts&feature=emb_logo.
[18] "All Metre Gauge tracks to be converted into Broad Gauge: Government," The Press Trust of India, 2017, https://www.dnaindia.com/india/report-all-metre-gauge-tracks-to-be-converted-into-broad-gauge-govt-2398137.
[19] "Indian Railways flags off first DEMU train services in Tripura between Dharmanagar to Sabroom; details here," Prasad, 2020, https://indiarailinfo.com/blog/post/4453337.
[20] S. Roy, S. Hore, S. Mitra, and G. Chaberek, "Delineating regional differentiation on the development of the railway infrastructure in Northeast India through an efficient synthetic indicator," *Transp. Probl.*, vol. 17, no. 3, pp. 149-162, 2022. https://doi.org/10.20858/tp.2022.17.3.13.
[21] S. Roy and S. Mitra, "Rail freight transport system in tripura: An analysis of performances and prospects," in *Railway Transportation in South Asia*, vol. 2021, pp. 103-130, 2021. https://doi.org/10.1007/978-3-030-76878-2.
[22] T. Funk and V. Hromádka, "Impact of the Railway Infrastructure Revitalization Projects on the Severity of Occurrences," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 960, pp. 1-9, 2020. https://doi.org/10.1088/1757-899X/960/3/032084.
[23] S. Roy and S. Mitra, "Railway stations of Tripura, India: An assessment of infrastructural conditions," In *Urbanization and Regional Sustainability in South Asia*, Belgium: Springer, 2019, pp. 177-200, 2019. https://doi.org/10.1007/978-3-030-23796-7_11.
[24] C. Mańkowski, D. Weiland, and B. Abramovic, "Impact of railway investment on regional development – case study of pomeranian metropolitan railway," *Promet-Traffic & Transport.*, vol. 31, no. 6, pp. 669-679, 2019. https://doi.org/10.7307/ptt.v31i6.3231.
[25] C. Blanquart and M. Koning, "The local economic impacts of high-speed railways: Theories and facts," *Eur. Transp. Res. Rev.*, vol. 9, pp. 1-14, 2017. https://doi.org/10.1007/s12544-017-0233-0.
[26] S. Roy and S. Mitra, "Railway transport system in Tripura, India: A geographical analysis," *Geogr Rev. India*, vol. 78, no. 1, pp. 40-57, 2016.
[27] D. Bogart and L. Chaudhary, "Regulation, ownership, and costs: A historical perspective from Indian railways," *Am Econ J.: Econ Policy*, vol. 4, no. 1, pp. 28-58, 2012. https://doi.org/10.1257/pol.4.1.28
[28] R. Damián and C. I. Zamorano, "Environmental impact assessment of high-speed railway tunnel construction: A case study for five different rock mass rating classes," *Transport. Geotech.*, vol. 36, pp. 1-11, 2022. https://doi.org/10.1016/j.trgeo.2022.100817.
[29] S. Lin, P. R. Dhakal, and Z. Wu, "The impact of high-speed railway on China's regional economic growth based on the perspective of regional heterogeneity of quality of place," *Sustain.*, vol. 13, no. 9, pp. 1-24, 2021. https://doi.org/10.3390/su13094820.
[30] T. O. Nyumba, C. C. Sang, D. O. Olago, R. Marchant, L. Waruingi, Y. Githiora, F. Kago, M. Mwangi, G. Owira, R. Barasa, and S. Omang, "Assessing the ecological impacts of transportation infrastructure development: A reconnaissance study of the Standard Gauge Railway in Kenya," PLoS One, vol. 16, no. 1, pp. 1-14, 2021. https://doi.org/10.1371/journal.pone.0246248.
[31] P. S. Lucas, R. G. de Carvalho, and C. Grilo, "Railway disturbances on wildlife: Types, effects, and mitigation measures," in *Railway Ecology*, 2017, pp. 81-99, 2017. https://doi.org/10.1007/978-3-319-57496-7_6.

[32] J. P. Rodrigue, C. Comtois, and B. Slack, *The Geography of Transport Systems*, New York, 2016, pp. 1-454, 2016.

[33] C. Dionelis and M. Giaoutzi, "Environmental and safety aspect in rail transport," *In 8th NECTAR Conference*, Las Palma, Athens, June 2-4, 2005.

[34] V. N. Plakhotnik, J. V. Onyshchenko, and L. A. Yaryshkina, "The environmental impacts of railway transportation in the Ukraine," *Transport. Res. Part D: Transport and Environ.*, vol. 10, no. 3, pp. 263-268, 2005. https://doi.org/10.1016/j.trd.2005.02.001.

[35] G. Debrezion, E. Pels, and P. Rietveld, "The impact of railway stations on residential and commercial property value: A meta analysis," *J. Real Estate Finan. Econ.*, vol. 35, pp. 161-180, 2007. https://doi.org/10.1007/s11146-007-9032-z.

[36] P. Mohammad, A. Goswami, and S. Bonafoni, "The impact of the land cover dynamics on surface urban heat island variations in semi-arid cities: A case study in Ahmedabad City, India, using multi-sensor/source data," *Sensor*, vol. 19, no. 17, pp. 1-20, 2019. https://doi.org/10.3390/s19173701.

[37] S. Mitra, S. Roy, and S. Hore, "Assessment and forecasting of the urban dynamics through lulc based mixed model: evidence from Agartala, India," *GeoJournal*, vol. 83, no. 4, pp. 1-24, 2022. https://doi.org/10.1007/s10708-022-10730-4.

[38] S. Saha, "A study of the geohydrological problems of the Khowai and Haora River Basins, West Tripura," Ph.D. Dissertation, Department of Geography and Disaster Management, Tripura University, India, 2014.

[39] S. Roy, S. Dhar, P. Debnath, and S. Mitra, "Externalities of railways in tribal area development: An evidence from Thailik Twisa, Tripura," in *Transitional Aspects of Indigenous People of North East India*, 2022, pp. 145-158, 2022.

[40] P. Debnath, R. Roy, and S. Mitra, "The growth pattern and future developmental trends of national highways in the north eastern states of India," *Indian J. Reg Scin,* vol. 53, no. 1, pp. 84-100, 2021.

[41] S. K. Sen, S. Gupta, and I. Mukhopadhyay, "Economic viability of alternative internal road network in tripura: an application of ahortest path algorithm," *Hill Geogr.*, vol. 29, no. 1, pp. 25-39, 2015.

[42] S. Mitra, S. Roy, and S. Dhar, "A geopolitical and regional sustainability of Sabroom Town, Tripura: A road map for future," In *Geoinformatics in Research and Development*, vol. 2021, pp. 128-151, 2021.