GeoJournal (2023) 88:1401–1413
https://doi.org/10.1007/s10708-022-10699-0

BR-174 highway, geotourism and socio-environmental conflicts in the northern remote regions of the Amazon

Ana Sibelonia Saldanha Veras · Diogo Guedes Vidal · Zujaja Wahaj · Waqas Ahmed · Nelson Azevedo Barros · Maria Alzira Pimenta Dinis

Accepted: 30 May 2022 / Published online: 29 June 2022

Abstract BR-174 in Brazil, also known as Manaus–Boa Vista, is a longitudinal highway that connects the Brazilian states of Mato Grosso, Rondônia, Amazonas and Roraima to Venezuela, being the only terrestrial connection between Roraima and the rest of Brazil. Its construction took place in 1968 and its inauguration in 1977, aiming to promote the interconnection of the State of Roraima, as a geopolitical strategy, with the rest of the country and, later, with South America. The construction of the BR-174 crossed the Waimiri Atroaris indigenous land, resulting in serious socio-environmental conflicts in the 1970s. Furthermore, recent research indicates that the deforestation process in the Amazon is associated with the opening of roads, as it favours the migratory flow, the occupation of land and logging. In this context, the arrival of migrants and, consequently, the pressing need to settle newly arrived people in search of land, favoured the damming of watercourses, the reduction of wild fauna and deforestation as a result of the construction of the road and neighbouring areas. However, and currently, BR-174 translates into a strategy of progress and communication, uniting adjacent communities, on the one hand, and, on the other, allowing the use of biophysical resources in favour of the development of geotourism. Considering this reality and from the perspective of the social and environmental transformations that have occurred, the objective of this paper is to analyse the potential of the BR-174 for the development of

A. S. S. Veras
Faculty of Science and Technology, University Fernando Pessoa, Praça Nove de Abril, 349, 4249-004 Porto, Portugal
e-mail: 39347@ufp.edu.pt

D. G. Vidal (✉)
Centre for Functional Ecology - Science for People & the Planet (CFE), TERRA Associate Laboratory, Department of Life Sciences, University of Coimbra, Calçada Martim de Freitas, 3000-456 Coimbra, Portugal
e-mail: diogoguedesvidal@hotmail.com

Z. Wahaj
Department of International Business and Marketing, NUST Business School, National University of Sciences and Technology, Islamabad 44000, Pakistan
e-mail: zujaja.wahaj@nbs.nust.edu.pk

W. Ahmed
Department of Operations and Supply Chain, National University of Sciences and Technology, Islamabad 44000, Pakistan
e-mail: dr.waqas.ahmed@nbs.nust.edu.pk

N. A. Barros · M. A. P. Dinis
UFP Energy, Environment and Health Research Unit (FP-ENAS), University Fernando Pessoa, Praça Nove de Abril, 349, 4249-004 Porto, Portugal
e-mail: nelson@ufp.edu.pt

M. A. P. Dinis
e-mail: madinis@ufp.edu.pt

geotourism, as a way of mitigating its socio-environmental impacts and connecting geographically remote regions. The qualitative nature approach is based on the treatment and analysis of available bibliographic and documental sources. As the only land connection in the State of Roraima, and in addition to the negative impacts on the socio-environmental profile of the region, it can be concluded that the BR-174 highway has the potential to be an element facilitating the promotion of geotourism in the remote region of Amazon, contributing to the socio-environmental safeguard of this region.

Keywords BR-174 highway · Amazon · Socio-environmental conflicts · Geotourism

Introduction

Roraima, the northernmost state of Brazil located in the northern part of the Amazon, underwent several significant changes under the responsibility of the Federal Government, particularly during military administrations (the 1960s to the 1980s). The opening of BR-174 (Fig. 1), a longitudinal highway, stands out for being the only land connection between the states of Mato Grosso, Rondônia, Amazonas and also with Venezuela. Furthermore, BR-174 is the only means of terrestrial communication between the state of Roraima and the rest of Brazil. Many cities in Roraima are considered Geographically Remote Locations (GRL), which are those that are far away from cities and places where most people live and are therefore difficult to get to. Despite the significant amount of research that has been conducted since the publication of the 2030 United Nations Agenda for Sustainable Development (Sachs et al., 2019; United Nations, 2015), with the mission to contribute to solve key issues of the Planet and achieve a fair future for the world, GRL have been put aside from the sustainable development discourse. Alongside, these communities are more likely to be significantly disadvantaged by the loss of connection to the country and the limited infrastructure associated with the locations in remote areas where they reside (Hall et al., 2020; Jaimes, 1994). BR-174 played an important role in the supply of foodstuffs from Amazonas and the Bolivarian Republic of Venezuela between 1980 and 1990, as well as in the supply of imported products such as cement and limestone (Zymler, 1999). This Pan-American Road system, which starts in the United States, cuts through Central America, crossing the coast of the Pacific Ocean and part of the Andes, passing through Colombia towards Caracas (Venezuela), has a length of 975.6 km that extends from Manaus to the Brazil-Bolivarian Republic of Venezuela border.

The consolidation of BR-174, when crossing the *Waimiri-Atroaris* indigenous land in Roraima territory, resulted in serious socio-environmental conflicts in the 1970s. The highway construction process caused a series of land appropriations and deforestation in indigenous lands, resulting in an imbalance of the ecosystem and triggering a health-disease process that led to the death of many indigenous people (Amorim et al., 2019; Miele et al., 2021; Rorato et al., 2021).

Regarding deforestation in the Amazon region, specifically Roraima, there was a different dynamic, as at the time it complied with the government's determination to link a territory to other regions. However, such actions resulted in processes of forest degradation, mining, diversion of watercourses, illegal logging, and the beginning of the imbalance in the Amazon ecosystem (Nepstad et al., 2014). Despite the aforementioned factors, new cartography is evidenced over time, reflecting the recent region's economic growth (Nascimento et al., 2021). Thus, the highway became a modal that generates benefits for the citizens of the region, namely for the export market related to the timber, livestock, agribusiness, and tourism sectors (Gollnow et al., 2018; Paiva et al., 2020).

Given the territorial extension of Roraima, which is the most remote Brazilian state, integrating the triple border of Brazil, Venezuela, and Guyana, it occupies a strategic space for centralist connectivity mainly in the capital, Boa Vista, and from it its distribution to the 14 Roraima municipalities. In this sense, highways represent a relevant mobility corridor, an emergency of road communication for the tourism sector and, consequently, the use of biophysical resources (Mahato & Jana, 2021; Mehdipour Ghazi et al., 2021). From this perspective, this paper aims to

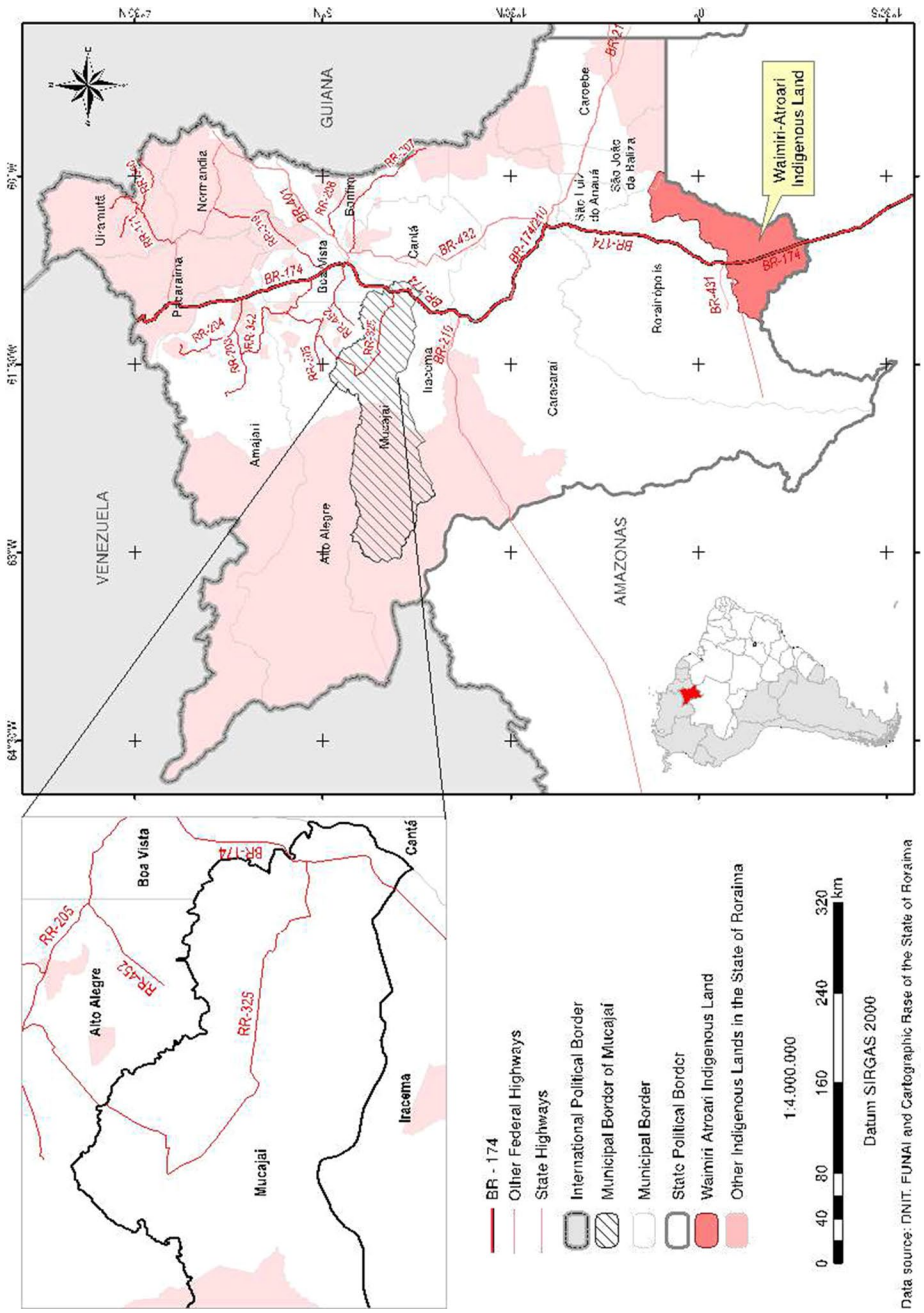

Fig. 1 Location map of the BR-174 highway with the main roads of the municipality of Mucajaí. Authors' elaboration

analyse the potential of the BR-174 for the development of geotourism, as a way of mitigating its socio-environmental impacts and connecting geographically remote regions.

The magnitude of the Amazon region and the people of the forest—geographically remote regions

Roraima holds the most extensive hydrographic basin on the Planet formed by a tangle of 25,000 km of navigable rivers, distributed over 6,925,674 km^2, of which 3,836,520 km^2 are in Brazilian territory. In this universe, the fluvial system is wide and unifies the several contiguous forest ecosystems that make up the South American Amazon, representing the most concentrated expression of life on Earth, as it contains the largest tropical forest in the world formed by a transnational complex. Among its natural resources, such as minerals, valuable woods and aromatic plants, there are also traditional communities and their respective cultures and traditions that make up a diverse socio-cultural mosaic (Bowman et al., 2021).

In Brazil, 45% of the municipalities have low levels of urbanization, 28% are considered rural, and 8% are GRL (IBGE - Instituto Brasileiro de Geografia e Estatística, 2017). Several studies reported that populations living in Brazilian GRL are neglected, presenting the lowest socioeconomic, human development and health indicators (Ranscombe, 2020; Targa et al., 2014). In these areas, geodiversity and natural resources are the main survival sources due to their potential to create employment opportunities and increase income (Veras et al. 2021a). The preservation of these recourses, and more importantly their regeneration, are crucial to move forward on a sustainable path to the GRL (Veras et al., 2020a; Wahl, 2016).

Due to the lack of transport infrastructure, the state of Roraima was awarded by the federal government, through the National Integration Program (Programa de Integração Nacional—PIN), with a budget allocation in the amount of Cr$ 2,000,000,000.00 (two billion cruzeiros) for the first stage, 1971–1974, of the construction of the highway. This endowment was also intended to connect dispersed populations and integrate them, translating into service to transport production to the centre, to value production in regional markets and also the return of industrialized products (Costa, 2020). However, the construction of the road generated, along with the economic benefits for the region, socio-environmental consequences such as deforestation, fragmentation of habitats, deaths of animals when crossing the road from one side to the other, and conflicts with the *Waimiri-Atroari* indigenous population (Nascimento et al., 2021). The concern with the demographic vacuum and the invitations by governments favoured the internal migration of people from various parts of Brazil to Roraima, resulting in the intensification of logging, hunting of exotic species, and illegal logging. On the other hand, it had repercussions on the increased accessibility of agricultural and industrial products, essential public services, such as access to education and health, and impacts arising from government programs that aimed at integrating and occupying a remote Amazon (Nascimento et al., 2021). Therefore, BR-174, like an axis of integration and sustainable development, aimed to reduce disparities (Lima et al., 2012).

The socio-environmental conflicts with the opening of BR-174

The *Waimiri-Atroari* ethnicity

Rivalry and violent aggression are common when local communities face imminent threats, such as the appropriation of land from their territory (Okeke, 2021; Sousa et al., 2020). During the execution of the BR-174 road construction project, the closed jungle region was affected. Despite the numerous pacification efforts that involved priests and FUNAI technicians in an attempt to persuade the indigenous people (IP) to withdraw from the road and thus avoid a confrontation against a large number of soldiers, the expedition to that region where the indigenous community that had a reputation as savages and cannibals were found, was understood by the IP as a sign of disrespect for customs and as an invasion of their territory. The expedition was not successful and the attempts at pacification were not effective, culminating in the execution of IP (Sousa et al., 2020). Several planes and helicopters shot down about forty-six IPs in one day. The survivors, as they attempted a peaceful approach, were met with bursts of machine

guns, decimating six villages. The remnants moved to distant regions of the Amazon. These facts were widely reported by the press in Amazonas, as if these IPs were against the development and progress of the region, distorting the history of the *Waimiri-Atroari* ethnic group (Sousa et al., 2020).

The Brazilian Army and the construction of the road

Major territorial works in the Amazon were of national interest, being carried out after the creation of the 6th Construction Engineering Battalion "Simon Bolívar" by Decree n. 63,184 on August 27, 1968, with headquarters in Boa Vista for the execution of military transport works. These works were important to take the state of Roraima out of isolation in the North and South direction and from the BR 401 to Bonfim, on the eastern border with the Cooperative Republic of Guyana. Conceived by the government of President Médice (1964–1974) to prioritize road transport, the National Integration Plan in the year 1970, with the motto: "Integrate so as not to Hand over" allowed for an occupation front in the Amazon. Within the portfolio, the plan prioritized the construction of the Transamazônica, meeting geopolitical strategies and the flow of wealth, expanding the agricultural frontier with the concept of living frontiers in the northern portion, a very important step toward the consolidation of the South American road network and the Pan-American highway system of Brazil, Venezuela, Uruguay, Argentina and Paraguay (Gill, 2021; Pavani and Mattioni 2020; Lima et al., 2012).

As a vital artery for communication and the flow of people and goods, the highway increased significantly and enabled the emergence of agglomerations around it, such as the Village of the National Institute of Colonization and Agrarian Reform, which directed migrants to the lots. In Vila Novo Paraíso, at the junction of the BR-210 and BR-174 roads, is where the first gas station known as the Quinhentos gas station appears, this name for being exactly at Km 500 of the BR-174, area in which many camps of the 6th Engineering and Construction Battalion and companies that worked on the stretch that headed towards the city of Boa Vista, capital of Roraima, settled (Monteiro and Laroque 2014; Neto, 2016; Oliveira et al., 2021).

The environmental impacts of BR-174 construction

The construction of road networks threatens many natural habitats of high conservation value, especially in tropical and remote regions. Although these highways promote communication among these regions and reduce physical barriers among people, the truth is that they bring negative consequences for ecosystems, translating into more severe impacts such as fires, soil erosion, landslides, and accumulation of sediments in the rich waters, as first-order rivers. During road construction, forests are cut, involving the felling of trees in corridors much wider than just the trail adjacent to the forest (Phillips et al., 2021). In the case of the Amazon, the massive opening of roads in the 1960s and 1970s provided access to loggers who, with their forestry tractors and chainsaws, gave place to the beginning of cattle raising and agriculture in the interior of the forest. Such environmental exploration, with contours uncontrolled and driven by the associated profit, will take about 75 to 100 years to be recovered (Johns et al., 1998).

Studies show that road construction with forest clearing has implications for carbon flux, such as necromass, i.e., all woody biomass contained in non-living parts in mineral or organic environments, an important component of the regional carbon cycle for mature tropical forests such as the case of the Amazon (Fearnside & Laurance, 2003; Feldpausch et al., 2005). Part of these areas was deforested for logging, some were converted into permanent public roads with a subsequent influx of biological invasions, and there is an increase in hunting pressure and the proliferation of shifting agriculture (Kleinschroth & Healey, 2017). In this context, it is worth remembering that to guarantee the sustainability of the forest, it is essential to also safeguard the conservation of game species, i.e., animals that are in natural freedom, therefore, guaranteeing the subsistence of millions of individuals in Nature and, thus, sustaining current lives and future ones (Oso & Babalola, 2021).

Geotourism as an interpretation of heritage today

Geotourism has as its anchor geoscience, whose contribution is critical to delivering the SDGs (Gill, 2017; Gill & Smith, 2021; Scown, 2020), particularly in GRL areas of the planet, where natural resources

are dominant (European Commission, 2021). Within the geosciences field, the geotourism activity aims for the conservation and protection of Nature, with more emphasis on the current Anthropocene era (Crutzen & Stoermer, 2000; Hose, 2006, 2012). Several studies contributed to share the geomorphological profile of regions around the world where geotourism represents an alternative to local communities' income (Dowling, 2014; Dowling & Newsome, 2018; Hose, 2011; Štrba et al., 2020; Veras et al., 2021b).

Public policies for tourism in Brazil are prepared and monitored by the Ministry of Tourism. A national effort has been made regarding the implementation of state tourism bodies, forums or tourism councils as a strategy to compose the Brazilian Tourism Map (Chaves & Secchi, 2022). However, in some Brazilian states, tourism is not considered a strategic priority for development, impacting the effective alignment of national public policy on tourist regionalization.

Geotourism is an activity not yet officialized by the Brazilian government regarding the economically classified segments. Therefore, a specific political instrumental on geotourism activity is missing. Nevertheless, some guidelines can be found at Law no. 6.938/1981 (Brazilian Federal Republic, 1981) which establishes the National Environment Policy and is considered the ground zero of environmental awareness. Concomitantly, the National Environment Council (CONAMA) (Brazilian Ministry of Environment, 2020a), a body created in 1982 of an advisory and deliberative nature of the National Environment System (SISNAMA) (Brazilian Ministry of Environment, 2020b), and supported by Article 4 of Law no. 9.985/2000 (Brazilian Federal Republic, 2000), is intended for the preservation of natural ecosystems. CONAMA was at the origin of the National System of Conservation Units (SNUC) (Brazilian Ministry of Environment, 2020c) and, among its objectives, it ensures the protection of the forms and processes supporting biodiversity. Administratively, the environmental legislation establishes the conditions, constraints and environmental control measures that must be obeyed by the entrepreneur, individual or legal entity to locate, install, expand and operate projects or activities that use resources considered effective or potentially polluting or those that, under in any way, may contribute to cause environmental degradation.

From north to south, the BR-174 route is almost entirely straight and in some stretches, it has curves marked by a vegetation cover of dense forest, savannah with bush vegetation, grasses, and small trees, grading to the relief of elevations ranging from 50 to 1,000 m (Veras et al., 2020b). The surroundings of BR-174 are a special area for the development of geotourism. It appears as an alternative for the preservation and safeguarding of natural heritage as a global practice. In the last fifteen years, geotourism has registered different interpretations of geo-objects and geo-heritages, turning to the understanding of places through a sustainable educational practice where local communities are the main agents of change (Matshusa et al., 2021).

In South Australia and Africa's GRL, their territories include ecological landscapes and indigenous histories that are protected and guaranteed in the Venice Charter published in 1964 (Torre, 2013). The processing begins with the choice of a place that should be the target of protection and conservation of its heritage for future generations, whose principle is in line with the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Union for Conservation of Nature (IUCN) and with the International Study Center for the Conservation and Restoration of Cultural Property (Lewis, 2020). Such examples should be taken as good practices to be replicated in similar contexts, namely in the GRL in the Amazon, being a challenge for the practice of geotourism, with a need for amenities to attract geotourists, since it is currently one of the activities with exponential growth, dynamic, which continuously interprets and reinterprets geological heritage (Mehdipour Ghazi et al., 2021).

Material and methods

Characterization of the research area

The studied area passes through the state of Roraima from North to South through the terrestrial modal that integrates the road course and promotes regional and national connectivity, linking the capitals of Manaus-AM to Boa Vista-RR. Finally, being paved in 1996, BR-174 crosses the municipalities of Rorainópolis, Caracaraí, Iracema, Mucajaí, Boa Vista (capital), towards the municipality of Pacaraima, on the border with the Bolivarian Republic of Venezuela. The climate for the region is the humid tropical type, with

the rainy season in the summer and dry in the winter, with average annual precipitation ranging between 1,750 and 2,075 mm annually and an average temperature of 27.4 °C and monthly mean variation intervals between 23.4 and 32.4 °C (Alvares et al., 2013). The municipalities of Rorainópolis, Caracaraí, Iracema and Boa Vista have soils in Hidromorphic Quartzous Sand. The municipality of Mucajaí follows the taxonomic unit of Red-Yellow Latosol, Neossol, Plinthosol, Gley Soil, Argisol, predominantly the Red-Yellow Latosol (Gama, 1983). The region's relief is formed by extensive flat surfaces, ranging from smooth to wavy, with the presence of Inselbergs and Bolders (isolated or grouped reliefs) that reach altitudes ranging from 80 to 160 m. Such singularities are formed by acidic volcanic rocks. In the Midwestern part of the Central Guyana Domain (CGD), there are high bands of metamorphism that carved gneiss rocks with altitudes ranging from 100 to 250 m (Holanda et al., 2014). The mosaic for this extension is formed by several forest formations, rainforest, flooded areas (*igapós* and floodplains), in dry land surface, with open areas in which the presence of *buritizais* is significant (*Mauritia fleuxuosa*). In this context, the highway with a road body is inserted, consisting of straights and curves, and has the signalling infrastructure and logistics to support the visitor who travels along the road.

Research strategy

The qualitative approach is based on the treatment and analysis of bibliographic, cartographic, and document sources available for the interpretation of the object under analysis – the construction of the BR-174 and the socio-environmental conflicts arising from it. The qualitative procedure is usually challenging, as it offers a deeper understanding of the content, it is complex, especially in the case of the object under study being the only land connection in the State of Roraima, in addition to the impacts on the socio-environmental profile of the region (Krippendorf, 2018).

For the composition of the cartographic products, the Geographic Information System (GIS) and ArcMap software version 10.3 were used, with the geographic cartographic projection (South America), central meridian − 62° and reference geodetic system: SIRGAS 2000. The cartographic scale used was: 1:4,000,000 from IBGE and INCRA for settlement projects. The vectors were used for the composition of the BR-174 highway, for indigenous lands and the continuous cartographic base of the State of Roraima on a scale of 1:100,000.

Results and discussion

BR-174, the only land road in the region, provides the traveller with a unique itinerary in the Northern Amazon, highlighting the route in which it is possible to combine the history of construction with the exuberant geotouristic landscapes, in addition to providing an ethnocultural experience when crossing the *Waimiri-Atroari* territory on Roraima territory.

Deforestation and its repercussions

With the increase in deforestation, there is an increase in the temperature of the Atlantic Ocean and droughts in the states of the North region, as a result of the increase in biomass (Sousa et al., 2020). Although at the time no legislation required action in the face of such crimes against the ecosystem, such an event was necessary for the integration of the population that was without a land connection. Such deforestation had repercussions on the quality of living beings in local habitats, in addition to contributing to the aggravation of climate change. On the other hand, the territory of the *Waimiri-Atroari* was shaken by noise, burning, and felling of trees, suffering a decline in ecosystems since the 1970s (Mahé et al., 2021; Wright et al., 2021).

The settlement projects were created by the National Institute for Colonization and Agrarian Reform (*Instituto Nacional de Colonização e Reforma Agraria*-INCRA), contributing to the occupation of the great Amazon void by migrants. Between 1970 and 1980, INCRA allocated 221.8 ha of land, an area with the capacity to receive up to 3.4 thousand families, and thus consolidated municipalities such as Rorainópolis in a total of sixty-seven settlement projects, benefiting a total of twenty-two thousand families, being considered one of the greatest anthropic pressures in the balanced landscape (Fig. 2).

The deforestation that took place led to disastrous consequences for biodiversity and geodiversity, areas that were later transformed into pastures for cattle, as

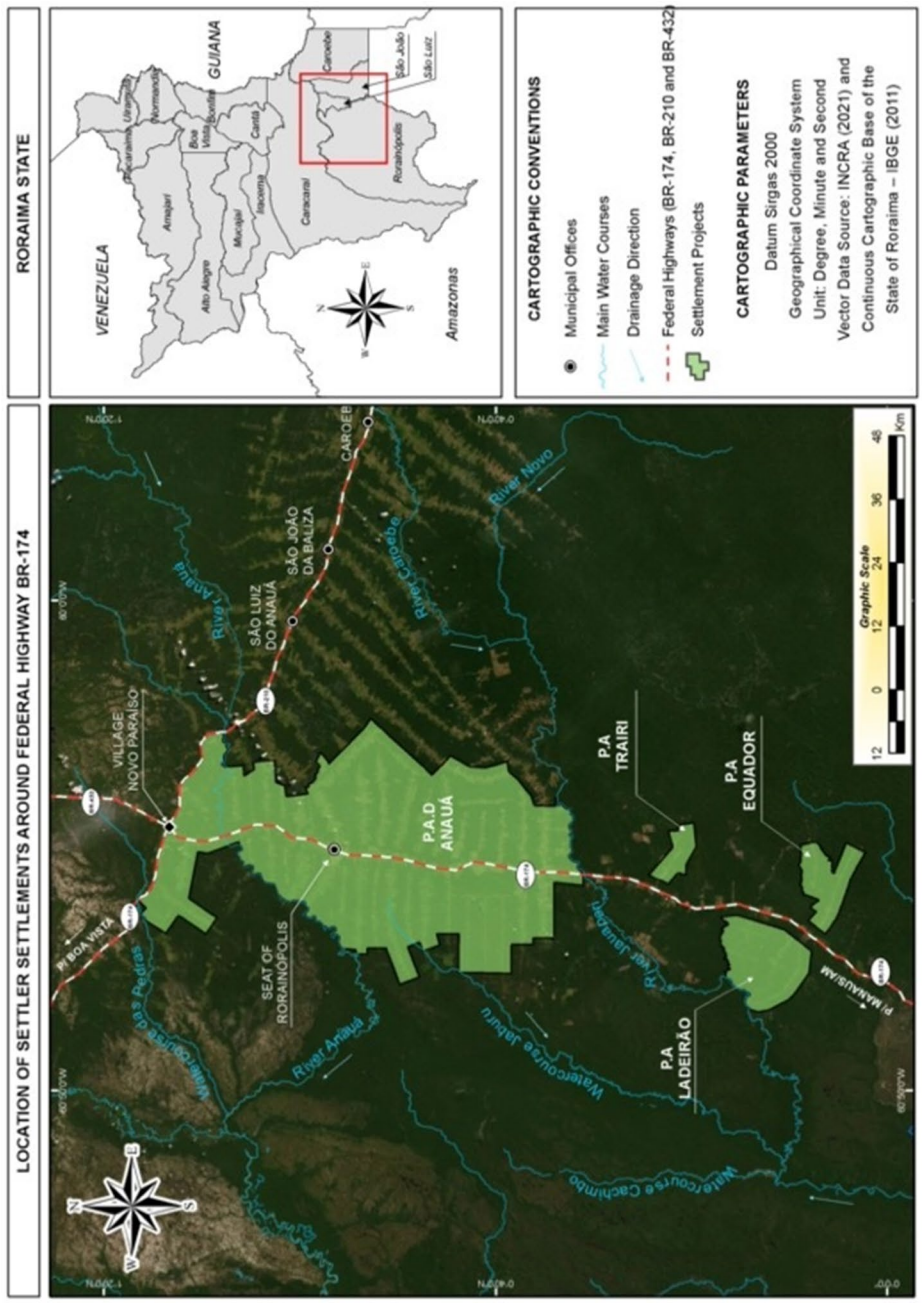

Fig. 2 Location of the Anauá Directed Settlements around the BR-174. Authors' elaboration

a trend for these areas as food support for the exploitation of beef and dairy cattle. The agricultural sector registers the breeds created by genetic similarity and resistance to ecotoparasites: Crioula, Guzerat, Gir, with the municipality of Mucajaí having the largest number of heads today, a favourable factor due to its geographic location.

The construction of the highway and favourable horizons for geotourism

The BR-174 Highway is commonly referred to in travel contexts. Its route passes through sparsely populated areas or wild areas suitable for outdoor living. Its potential goes beyond the social and economic aspects, found in its environmental aspects, and after its asphalting, a factor that promotes the development of tourism and geotourism, materializing in the establishment of companies that provide tourist services in the surrounding areas in the directions Manaus-AM to Boa Vista, as a tourist distribution centre.

Infrastructure and highway projects bring together many stakeholders, crossing different and sometimes contradictory political, social, economic, and cultural views. The BR-174 highway can be considered one of the main achievements in the history of the state of Roraima. From there, the visitor has the opportunity to explore the neighbouring roads, which are roads that connect to the villages. The consolidation of the highway allows for exploration and experience of the deeper Amazon, contacting unique scenarios in Roraima territory, in the first image the beginning of the opening of the road in the predominant forest ecosystem km 180, the second image already at km 200 shows compaction of landfill and natural aggregates suitable for traffic under the climatic conditions of the Amazon.

The unmistakable connection of the BR-174 highway boosted internal and international integration to contemplate the landscape, with the dominant green of the forest, plains, and savannah areas. BR-174 provides vertical signage and a shoulder area for services to visitors from all major capitals (Table 1).

Once the relevance of the BR-174 highway has been recognized, the landscape presents itself with its majesty and includes infrastructure to support the geotourist, so that he or she can get on and off along the road. Complementing the list of tourist services available to geotourists, there are hotels, motels, local guides and conductors, mechanical assistance, convenience stores, mini-market, tour package sales agency and the host community represented by native and non-native people.

As a legacy of past generations, but also a legacy for the coming years, the geotourism activity can contribute not only to the sustainability of Amazon but also to the identification and enhancement of persistent environmental issues, thus promoting policies to safeguard the humanity's common goods (Hall & Saarinen, 2010; Vieira, 2014). Furthermore, it is an activity that brings socioeconomic benefits through the sustainable use of geological structures and unique landscapes (Mikhailenko & Ruban, 2019; Veras et al., 2020a; Wu, 2013). It allows to register processes, aesthetics, natural beauty and local culture for sustainable planning, anchored in the opportunities and limitations of best practices (Maghsoudi et al., 2019; Shekhar et al., 2019; Tourtellot, 2016).

It is worth noting that a sustainable geotourism plan can define strategies for living in harmony with Nature, in common with the participation of the local communities, thus allowing to point out the best practices for safeguarding both the natural and cultural resources, in addition to observing the carrying capacity (Veras, et al., 2021a, 2021b) of specific regions towards sustainability (Assante et al., 2012). GRL can be considered as potentially touristic areas, thus offering a specific geotouristic destination that will depend on the available potential recreational and environmental security in forests, ski slopes, lakes, rivers, mountains or golf courses, where it is possible to contemplate the highlighted physiographic characteristics, and where the right to enjoy a healthy environment is also considered indispensable (Balaguer & Cantavella-Jordá, 2002; Hall & Saarinen, 2010; Ogunmola & Daniel, 2020). The geotourism approach is anchored in the local culture and supports and enhances the identity of the territory, being crucial in advancing the SDGs.

The involvement of local communities in all geoconservation actions, integrating the geotourism activity as a whole, could be an interesting strategy for a co-management of geosites in GRL, with mutual gains for the environment and the society, also contributing to improve the resilience of the communities (Tavares et al., 2015). Alongside this, is also necessary to develop synergies between municipalities and regions since these spaces of

Table 1 Distances from Boa Vista (capital of Roraima) to the main Brazilian cities and neighbouring countries

Roraima-North of Brasil	Capital	Distance (Km)*	Distance (Km)**	Bordering Country with Roraima (Km)	
				Venezuela- capital: Caracas	Guyana-capital Georgetown
Boa Vista, using BR-174* Mucajaí, using BR-174**	Manaus	783	731	1.582	641
	Belém	1.435	1.384		
	Porto Velho	1.620	1.569		
	Rio Branco	2.182	2.131		
	Macapá	2.293	2.242		
	Goiânia	2.503	2.452		
	Campo Grande	2.668	2.617		
	Palmas	4.357	4.306		
	Vitória	3.397	3.346		
	Salvador	3.014	2.963		
	Fortaleza	5.099	5.048		
	São Paulo	3.306	3.255		
	Belo Horizonte	3.119	3.068		
	Brasília	2.501	2.450		
	Rio de Janeiro	3.434	3.383		
	Porto Alegre	3.792	3.741		

geodiversity can integrate different municipalities and states, which implies a necessary shared sustainable management vision (Castro et al., 2016). The development of these visions aligned with geotourism activities should assure that no power relations between all actors involved, which is a key question regarding the role of this activity to mitigate socio-environmental conflicts. In this sense, the local sustainability framed by geotourism must go far beyond the benefits to the communities involved, and integrate their voices and culture into the activity design process.

Conclusions

The consolidation of BR-174, and the entire process related to its implementation, brought about a set of significant changes in the region's panorama. Despite the socio-environmental conflicts identified, which reveal deficiencies in intercultural communication and the inexistence of mediation practices, the truth is that the highway helped to relocate the state of Roraima and the GRL on the map of Brazil. Alongside, the benefits that such transport infrastructure has had in improving the living standards of local populations and in the communication link of many small and medium-sized Amazonian cities should be highlighted. The efficient management of these highways requires planning of services, and the provision of services must guarantee economic compensation for the citizen involved.

Geotourism can act as this compensation, encouraging citizens to recognize and promote their wealth and the feeling of belonging to a particular place. On the other hand, through its knowledge, it enhances the gain of financial resources, in addition to contributing to the conservation of geodiversity. Therefore, it is concluded that the activities that have emerged around the BR-174 highway are essential tools, when properly planned, contributing to the reduction of environmental risks, helping to preserve geodiversity and enhancing the value of endogenous products.

The transformations of geotouristic spaces stimulate knowledge about the Amazon region, boosting sustainable practices combined with a logic of mimicry, subsidizing sustainable businesses, and using the knowledge of the indigenous culture of the *Waimiri-Atroari* and non-indigenous communities about landscapes, empowering the Amazon region.

Acknowledgements The authors would like to thank to UFP Energy, Environment and Health Research Unit (FP-ENAS), funded by Fundação para a Ciência e a Tecnologia (FCT), in the scope of FCT Project UID/Multi/04546/2019 and to Professor Francisco dos Santos Panero, from the Federal University of Roraima, Brazil, for your valuable inputs to the work. Diogo Guedes Vidal was funded by the Fundação para a Ciência e a Tecnologia (FCT, I.P.) through the Doctoral Grant SFRH/BD/143238/2019.

Declarations

Conflict of interest No potential conflict of interest was reported by the authors.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

References

Alvares, C. A., Stape, J. L., Sentelhas, P. C., De Moraes Gonçalves, J. L., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift, 22*(6), 711–728. https://doi.org/10.1127/0941-2948/2013/0507

Amorim, R. F., Machado, J. A., da Silva, K. F. T., & Porto, F. (2019). Indigenous health and nursing in Roraima in the 1970s. *Revista Brasileira De Enfermagem, 72*(4), 848–853. https://doi.org/10.1590/0034-7167-2017-0791

Assante, L. M., Wen, H. I., & Lottig, K. J. (2012). Conceptualization of modeling resident attitudes on the environmental impacts of tourism: A case study of Oahu Hawaii. *Tourism Planning & Development, 9*(2), 101–118. https://doi.org/10.1080/21568316.2011.631354

Balaguer, J., & Cantavella-Jordá, M. (2002). Tourism as a long-run economic growth factor: The Spanish case. *Applied Economics, 34*(7), 877–884. https://doi.org/10.1080/00036840110058923

Bowman, K. W., Dale, S. A., Dhanani, S., Nehru, J., & Rabishaw, B. T. (2021). Environmental degradation of indigenous protected areas of the Amazon as a slow onset event. *Current Opinion in Environmental Sustainability, 50*, 260–271. https://doi.org/10.1016/j.cosust.2021.04.012

Brazilian Federal Republic. Decreto-Lei n. 6.938 de 31de Agosto. (1981). Dispõe sobre a Política Nacional de Meio Ambiente, e dá outras providencias. Coleções de Leis do Brasil. Seção 1. Diário Oficial da União de 2 de setembro de 1981 (1981). https://www2.camara.leg.br

Brazilian Federal Republic. Lei n. 9.985, de 18 de julho de. (2000). Dispõe sobre o Sistema Nacional de Unidades de Conservação-SNUC e dá outras providencias (2000). http://www.planalto.gov.br/ccivil_03/decreto/2002/d4340.html

Brazilian Ministry of Environment. (2020a). CONAMA—Conselho Nacional de Meio. http://www2.mma.gov.br/port/conama/. Accessed 11 November 2020a

Brazilian Ministry of Environment. (2020b). Sistema Nacional do Meio Ambiente. https://www.mma.gov.br/governanca-ambiental/sistema-nacional-do-meio-ambiente.html. Accessed 11 November 2020b

Brazilian Ministry of Environment. (2020c). Sistema Nacional de Unidades Conservação - SNUC. https://www.mma.gov.br/areas-protegidas/unidades-de-conservacao/sistema-nacional-de-ucs-snuc.html. Accessed 11 November 2020c

Castro, A. R. S. F., de Mansur, K. L., & de Carvalho, I. S. (2016). Diagnóstico da relação da comunidade com o patrimônio geológico por meio de instrumento de coleta de dados. *Terrae Didatica, 11*(3), 162–172. https://doi.org/10.20396/td.v11i3.8643644

de Chaves, T. J., & Secchi, L. (2022). O Plano Nacional de Turismo Brasileiro (2003–2022): uma análise do processo de formação da agenda regional: [The Brazilian Tourism National Policy (2003 to 2022): An analysis of the Formation of the subnational regional of the subnational regional agenda. *Revista Eletrônica De Administração e Turismo, 16*(1), 134–148.

Crutzen, P., & Stoermer, E. (2000). The 'Anthropocene.' *Global Change Newsletter, 41*, 17–18.

Dowling, R. K. (2014). Global geotourism—an emerging form of sustainable tourism. *Czech Journal of Tourism*. https://doi.org/10.2478/cjot-2013-0004

Dowling, R., & Newsome, D. (2018). Geotourism: definition, characteristics and international perspectives. In R. Dowling & D. Newsome (Eds.), *Handbook of Geotourism* (pp. 1–22). Edward Elgar.

European Commission. (2021). User uptake case: Earth Observation for SDGs. *Knowledge Centre on Earth Observation*. https://knowledge4policy.ec.europa.eu/earth-observation/user-uptake-case-earth-observation-sdgs_en. Accessed 28 July 2021

Fearnside, P. M., & Laurance, W. F. (2003). Comment on "Determination of deforestation rates of the world's humid tropical forests." *Science, 299*, 5609.

Feldpausch, T. R., Jirka, S., Passos, C. A. M., Jasper, F., & Riha, S. J. (2005). When big trees fall: Damage and carbon export by reduced impact logging in southern Amazonia. *Forest Ecology and Management, 219*(2–3), 199–215. https://doi.org/10.1016/j.foreco.2005.09.003

Gama, J. R. N. (1983). *Levantamento de reconhecimento de média intensidade dos solos e avaliação da aptidão agrícola das terras da área do Pólo Roraima*. EMBRAPA-SNLCS.

de Gil, H. F. C. (2021). O Pensamento Geopolítico de Golbery do Couto e Silva e os povos tradicionais na Amazônia: uma relação tensa: [The Geopolitical Thought of Golbery do Couto e Silva and the traditional peoples in the Amazon: a tense relationship]. *Revista Geopolítica Transfronteiriça, 1*(1), 120–140.

Gill, J. C. (2017). Geology and the Sustainable Development Goals. *Episodes, 40*(1), 70–76. https://doi.org/10.18814/epiiugs/2017/v40i1/017010

Gill, J. C., & Smith, M. (2021). *Geosciences and the sustainable development goals*. Springer International Publishing. https://doi.org/10.1007/978-3-030-38815-7

Gollnow, F., de Hissa, L. B. V., Rufin, P., & Lakes, T. (2018). Property-level direct and indirect deforestation for soybean production in the Amazon region of Mato Grosso, Brazil. *Land Use Policy, 78*, 377–385. https://doi.org/10.1016/j.landusepol.2018.07.010

Hall, C. M., & Saarinen, J. (2010). Geotourism and climate change paradoxes and promises of Geotourism in polar regions. *Téoros, 29*(2), 77–86. https://doi.org/10.7202/1024873ar

Hall, N. L., Creamer, S., Anders, W., Slatyer, A., & Hill, P. S. (2020). Water and health interlinkages of the sustainable development goals in remote Indigenous Australia. *NPJ Clean Water*. https://doi.org/10.1038/s41545-020-0060-z

Holanda, J. R., Marmos, J. L., & Maia, M. A. M. (2014). *Geodiversidade do Estado de Roraima [Geodiversity of Roraima State]*. CPRM.

Hose, T. (2011). The English Origins of Geotourism (as a vehicle for geoconservation) and their relevance to current studies. *Acta Geographica Slovenica, 51*(2), 343–359. https://doi.org/10.3986/AGS51302

Hose, T. A. (2006). Geotourism and interpretation. In R. K. Dowling & D.B.T.-G. Newsome (Eds.), *Geotourism: Sustainability, impacts and management* (pp. 221–241). Butterworth-Heinemann.

Hose, T. A. (2012). Editorial: Geotourism and geoconservation. *Geoheritage, 4*(1–2), 1–5. https://doi.org/10.1007/s12371-012-0059-z

IBGE - Instituto Brasileiro de Geografia e Estatística. (2017). *Classificação e caracterização dos espaços rurais e urbanos do Brasil: Uma primeira aproximação*. IBGE.

Jaimes, R. (1994). Reaching remote areas in Latin America. *Planned Parenthood Challenges, 1*, 43–46.

Pavani, J., & Mattioni, V. (2020). *Memórias de um fotógrafo topógrafo: a história de Luiz Mário Severo Ávila e a construção da BR-174: [Memories of a topographer photographer: the story of Luiz Mário Severo Ávila and the construction of the BR-174]*. Mogiana.

Kleinschroth, F., & Healey, J. R. (2017). Impacts of logging roads on tropical forests. *Biotropica, 49*(5), 620–635. https://doi.org/10.1111/btp.12462

Krippendorf, K. (2018). *Content analysis: An introduction to its methodology*. SAGE Publications Inc.

Lewis, I. D. (2020). Linking geoheritage sites: Geotourism and a prospective Geotrail in the Flinders Ranges World Heritage Nomination area, South Australia. *Australian Journal of Earth Sciences, 67*(8), 1195–1210. https://doi.org/10.1080/08120099.2020.1817147

Lima, W. T., Silva, I. O., & Sousa, L. F. (2012). Breve retrospectiva das estratégias geopolíticas de incorporação territorial da amazônia Brasileira. *Espaco Geografico Em Analise, 24*, 18–27. https://doi.org/10.5380/raega.v24i0.26206

Maghsoudi, M., Moradi, A., Moradipour, F., & Nezammahalleh, M. A. (2019). Geotourism development in world heritage of the lut desert. *Geoheritage, 11*(2), 501–516. https://doi.org/10.1007/s12371-018-0303-2

Mahato, M. K., & Jana, N. C. (2021). Exploring the potential for development of Geotourism in Rarh Bengal, Eastern India using M-GAM. *International Journal of Geoheritage and Parks*. https://doi.org/10.1016/j.ijgeop.2021.05.002

Mahé, G., Descroix, L., Laraque, A., Ribolzi, O., & Lacombe, G. (2021). Multiscale impacts of anthropogenic and climate changes on tropical and mediterranean hydrology. *Water (switzerland)*. https://doi.org/10.3390/w13040491

Matshusa, K., Thomas, P., & Leonard, L. (2021). A methodology for examining geotourism potential at the Kruger National Park, South Africa. *GeoJournal of Tourism and Geosites, 34*(1), 209–217. https://doi.org/10.30892/gtg.34128-639

Mehdipour Ghazi, J., Hamdollahi, M., & Moazzen, M. (2021). Geotourism of mining sites in Iran: An opportunity for sustainable rural development. *International Journal of Geoheritage and Parks, 9*(1), 129–142. https://doi.org/10.1016/j.ijgeop.2021.02.004

Miele, P., Di Napoli, M., Guerriero, L., Ramondini, M., Sellers, C., Annibali Corona, M., & Di Martire, D. (2021). Landslide awareness system (Laws) to increase the resilience and safety of transport infrastructure: The case study of pan-American highway (Cuenca–Ecuador). *Remote Sensing*. https://doi.org/10.3390/rs13081564

Mikhailenko, A. V., & Ruban, D. A. (2019). Geo-heritage specific visibility as an important parameter in Geo-Tourism resource evaluation. *Geosciences, 9*(4), 1–11. https://doi.org/10.3390/geosciences9040146

Monteiro, E. W. Q., da Laroque, L. F., & S. (2014). Vila Novo Paraíso-RR: a construção de um espaço na Amazônia Brasileira: [Vila Novo Paraíso-RR: the construction of a space in the Brazilian Amazon]. *GEOUSP, 18*(3), 594–608.

de Nascimento, E., & S., da Silva, S. S., Bordignon, L., de Melo, A. W. F., Brandão, A., Souza, C. M., & Silva Junior, C. H. L. (2021). Roads in the southwestern amazon, state of acre, between 2007 and 2019. *Land, 10*(2), 1–12. https://doi.org/10.3390/land10020106

Nepstad, D., McGrath, D., Stickler, C., Alencar, A., Azevedo, A., Swette, B., et al. (2014). Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains. *Science, 344*(6188), 1118–1123. https://doi.org/10.1126/science.1248525

Neto, T. O. (2016). A geopolítica rodoviária na Amazônia: BR 210 ou grande Perimetral Norte: [Road geopolitics in the Amazon: BR 210 or large North Perimetral]. *Revista De Geopolítica, 6*(1), 123–142.

Ogunmola, M. O., & Daniel, O. (2020). Impact of visual arts in hospitality industry as mean of economics stability in Nigeria. *EPRA International Journal of Research and Development, 5*(4), 6–11. https://doi.org/10.36713/epra2016

Okeke, C. E. (2021). Rethinking the rights of indigenous peoples in international law: Africa in perspective. *African Journal of Law and Human Rights, 5*(2), 40–54.

Oliveira, I. A. D., de Sales, H. J., & Lacerda, E. G. (2021). Rodovias na Amazônia e os processos de territorialização: o caso da BR-210, Sudeste de Roraima: [Highways in the Amazon and territorialization processes: the case of BR-210, Southeast of Roraima]. *Revista Geográfica Acadêmica, 15*(1), 21–32.

Oso, A. O., & Babalola, F. D. (2021). Effect of Stakeholders' involvement in forest policy implementation in Southwestern Nigeria. *Journal of Research in Forestry, Wildlife & Environment, 13*(2), 161–167.

Paiva, P. F. P. R., de Lourdes Pinheiro Ruivo, M., da Silva Júnior, O. M., de Nazaré Martins Maciel, M., Braga, T. G. M., de Andrade, M. M. N., et al. (2020). Deforestation in protect areas in the Amazon: A threat to biodiversity. *Biodiversity and Conservation, 29*(1), 19–38. https://doi.org/10.1007/s10531-019-01867-9

Phillips, B. B., Bullock, J. M., Osborne, J. L., & Gaston, K. J. (2021). Spatial extent of road pollution: A national analysis. *Science of the Total Environment,*. https://doi.org/10.1016/j.scitotenv.2021.145589

Ranscombe, P. (2020). Rural areas at risk during COVID-19 pandemic. *The Lancet Infectious Diseases, 20*(5), 545. https://doi.org/10.1016/S1473-3099(20)30301-7

Rorato, A. C., Picoli, M. C. A., Verstegen, J. A., Camara, G., Bezerra, F. G. S., & Escada, M. I. S. (2021). Environmental threats over amazonian indigenous lands. *Land*. https://doi.org/10.3390/land10030267

Sachs, J. D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six transformations to achieve the sustainable development goals. *Nature Sustainability, 2*(9), 805–814. https://doi.org/10.1038/s41893-019-0352-9

Scown, M. W. (2020). The sustainable development goals need geoscience. *Nature Geoscience, 13*(11), 714–715. https://doi.org/10.1038/s41561-020-00652-6

Shekhar, S., Kumar, P., Chauhan, G., & Thakkar, M. G. (2019). Conservation and sustainable development of geoheritage, geopark, and geotourism: A case study of Cenozoic Successions of Western Kutch India. *Geoheritage, 11*(4), 1475–1488. https://doi.org/10.1007/s12371-019-00362-5

de Sousa, A. L. M., de Sousa, P. M., & de Souza, T. M. (2020). Los pueblos indígenas Waimiri-Atroari y la expansión de grandes proyectos capitalistas en la Amazonía brasileña: [The Waimiri-Atroari Indigenous Pueblos and the expansion of large capitalist projects in the Brazilian Amazon]. *Batey, 13*(1), 53–70.

Štrba, L., Kolackovská, J., Kudelas, D., Kršák, B., & Sidor, C. (2020). Geoheritage and geotourism contribution to tourism development in protected areas of Slovakia-theoretical considerations. *Sustainability*. https://doi.org/10.3390/su12072979

Targa, L. V., Wynn-Jones, J., Howe, A., Anderson, M. I. P., Lopes, J. M. C., Lermen Junior, N., et al. (2014). Declaração de Gramado pela Saúde Rural nos países em desenvolvimento. *Revista Brasileira De Medicina De Família e Comunidade, 9*(32), 292–294. https://doi.org/10.5712/rbmfc9(32)982

Tavares, A. O., Henriques, M. H., Domingos, A., & Bala, A. (2015). Community involvement in geoconservation: A conceptual approach based on the geoheritage of South Angola. *Sustainability, 7*(5), 4893–4918. https://doi.org/10.3390/su7054893

Torre, M. (2013). Values and heritage conservation. *Heritage & Society, 6*(2), 155–166. https://doi.org/10.1179/21590 32x13z.00000000011

Tourtellot, J. B. (2016). The Geotourism Approach: an overview of implications and potential effects. *le Pagine di Risposte Turismo*. http://www.risposteturismo.it/Public/lePaginediRT/due2016_lePaginediRT_JBTourtellot.pdf

United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015, A/RES/70/1*. http://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf

Veras, A. S. S., Vidal, D. G., Barros, N., & Dinis, M. A. P. (2020a). Landscape sustainability: Contribution of Mucajaí-RR (Brazil) region. In W. L. Filho, A. M. Azul, L. Brandli, P. G. Özuyar, & T. Wall (Eds.), *Responsible consumption and production, encyclopedia of the UN sustainable development goals* (pp. 1–7). Springer Nature Switzerland AG.

Veras, A. S. S., Vidal, D. G., Barros, N., & Dinis, M. A. P. (2020b). Geodiversidade como recurso do geoturismo: uma experiência na região Central de Roraima, Brasil. In M. Oliveira, N. Carvalho, & O. Santos (Eds.), *Atas do IV Congresso Internacional Educação, Ambiente e Desenvolvimento* (pp. 384–390). OIKOS.

Veras, A. S. S., Vidal, D. G., Barros, N. A., & Pimenta Dinis, M. A. (2021a). The davi trail in Mucajaí, Roraima, Brazil: An experience to (re)connect and protect nature. *GeoJournal*. https://doi.org/10.1007/s10708-021-10484-5

Veras, A. S. S., Vidal, D. G., Dinis, M. A. P., & Barros, N. A. (2021b). Rufina beach and sustainable development: The role of women in Mucajaí, RR, Brazil. In W. L. Filho, U. Tortato, & F. Frankenberger (Eds.), *Integrating social responsibility and sustainable development: Addressing challenges and creating opportunities* (pp. 365–376). Springer.

Vieira, A. (2014). O Património geomorfológico no contexto da valorização da geodiversidade: Sua evolução recente, conceitos e aplicação. *Cosmos, 7*(1), 28–59.

Wahl, D. (2016). *Designing regenerative cultures*. Triarchy Press.

Wright, J. L., Bomfim, B., Wong, C. I., Marimon-Júnior, B. H., Marimon, B. S., & Silva, L. C. R. (2021). Sixteen hundred years of increasing tree cover prior to modern deforestation in Southern Amazon and Central Brazilian savannas. *Global Change Biology, 27*(1), 136–150. https://doi.org/10.1111/gcb.15382

Wu, J. (2013). Landscape sustainability science: Ecosystem services and human well-being in changing landscapes. *Landscape Ecology, 28*(6), 999–1023. https://doi.org/10.1007/s10980-013-9894-9

Zymler, B. (1999). Governo do Estado de Roraima-Obras de Construção e Pavimentação da Rodovia BR-174. [Government of the State of Roraima-Construction and Paving Works on Highway BR-174]. *Revista Do TCU, 80*, 247–315.