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Research Article

The impact of Climate Change on the transportation in Binh Thuan Province

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Abstract: The paper provides information on the assessment of the impact of the change in temperature and rainfall under the RCP4.5 scenario in the middle and end of 21st century on the transportation in Binh Thuan Province. According to the simulation results, the temperature in Binh Thuan Province increases by 1.29–1.43ºC in the middle of 21st century and 1.77–1.87ºC by the end of the 21st century. Rainfall increases from 8.5–14% in the middle of the 21st century and 9.5–21.6% by the end of the 21st century. This has an impact on road, rail and seaport operations. The roads are at risk of deforming, increasing service and maintenance costs.

Keywords: Temperature; Rainfall; Climate change scenarios; Impacts; Transportation.

1. Introduction

Binh Thuan is the southernmost coastal province of Central Vietnam, with a tropical monsoon climate characterized by high temperature (26.5–27.5ºC), large amount of sunshine and low rainfall (800–1800 mm) without a cold winter. According to a series of statistics at Phan Thiet station in the period of 1984–2019, the temperature tends to increase by 0.2ºC per decade and the rainfall tends to increase by 16 mm per decade. Severe drought in a 6–month dry season in Binh Thuan occurs with a frequency of 7.1% and extremely severe drought occurs with a frequency of 3.7%. On average, there are 0.48 storms and tropical depressions each year directly affecting the province. The sea level at Phu Quy station tends to increase by 5.3 cm per decade. The trends of climate change are becoming more and more obvious; the weather is becoming more complicated with the increase in heavy rains, droughts, high tides, floods, storms, inundation, saltwater intrusion and coastal erosion. Heavy rains accompanied by tornadoes have torn off roofs, damaged houses, and made power poles and roadside trees toppled in recent years in Lac Tanh town, Duc Binh and Duc Thuan communes (Tanh Linh district). The dam of the Ocean Valley project was broken due to the heavy rain in Tien Thanh commune (Phan Thiet), causing rapid flow with mud and sand, resulting in landslides into DT 719 (Provincial Road 719). In addition, the power consumption also increases in the context of the temperature increase [1–6]. Based on the assessment on impacts of climate change and sea level rise [7–10], the study on the results of research on assessing the impacts of climate change in Binh Thuan Province on the transport industry with key sub–sectors (roads, railways and seaports) will have a certain contribution to strengthening the local capacity in responding to climate change.

2. Materials and Methods

2.1. Materials

The temperature and rainfall data at Phan Thiet station and in neighboring provinces of Binh Thuan province in the period of 1984–2019 are used to develop scenarios and verify the climate models. The collected maps are DEM digital elevation maps and maps of the transport sectors [6].

2.2. Methods

The impact of climate change on the Transport sector is evaluated based on the combination of 03 methods including extrapolation of historical monitoring data, numerical model and workshops. The statistics of historical data and data on the impact of climate change and sea level rise are to give an overview of the impacts in the past. The numerical model is used to predict future impacts through extrapolation of monitoring factors. And the analytical method is based on consultation and assessment of experts through the workshop to analyze the impacts of climate change on the subjects under consideration. The three applicable approaches consist of the impact approach, interactive approach, and integrated approach [11–16]. The RCP 4.5 scenario – the climate change scenario – which is used for impact assessment is detailed from the results of regional climate models for Binh Thuan province as show in Table 1.

Table 1. Regional climate models used in the calculation of climate change scenarios for Binh Thuan Province.

No.	Model	Boundary conditions originating from a global model	Resolution	Data retention period	
				Base period	RCP4.5
1	CCAM	ACCESS1–0	10km	1970–2005	2006–2099
2		CCSM4			
3		CNRM–CM5			
4		GFDL–CM3			
5		MPI–ESM–LR			
6		NorESM1–M			
7	RegCM	ACCESS1–0	20km	1980–2000	2046–2065
8		NorESM1–M			2080–2099
9	PRECIS	HadGEM2–ES	25km	1960–2005	2006–2099
10		GFDL–CM3			
11	CLWRF	CNRM–CM5	30km	1980–2005	2006–2099
12		NorESM1–M			

3. Result and discussion

3.1. Impacts of temperature rise

According to the RCP 4.5 scenario, the temperature of the roads located in the study area increases from 1.29–1.43^{o}C in the middle of the century and 1.77–1.87^{o}C by the end of the century. The temperature rise makes the concrete on the pavement soft and expanding, resulting in risks of cracking and rutting of wheel tracks on the asphalt pavement. The North–South railway passing through the province is also suffered from the impacts of the increase in

temperature. The temperature rise also causes the risks of deforming and shortening the life of the train and related equipment. The embankment and breakwater areas (Vinh Tan port, Phan Thiet port) are located in the area where the temperature increases from 1.39–1.4°C; 1.8 –1.81°C in the middle and end of the century respectively. The temperature rises results in the increase in the maintenance costs of embankment systems. The impacts of temperature variation are as shown in Figure 1 and Table 2.

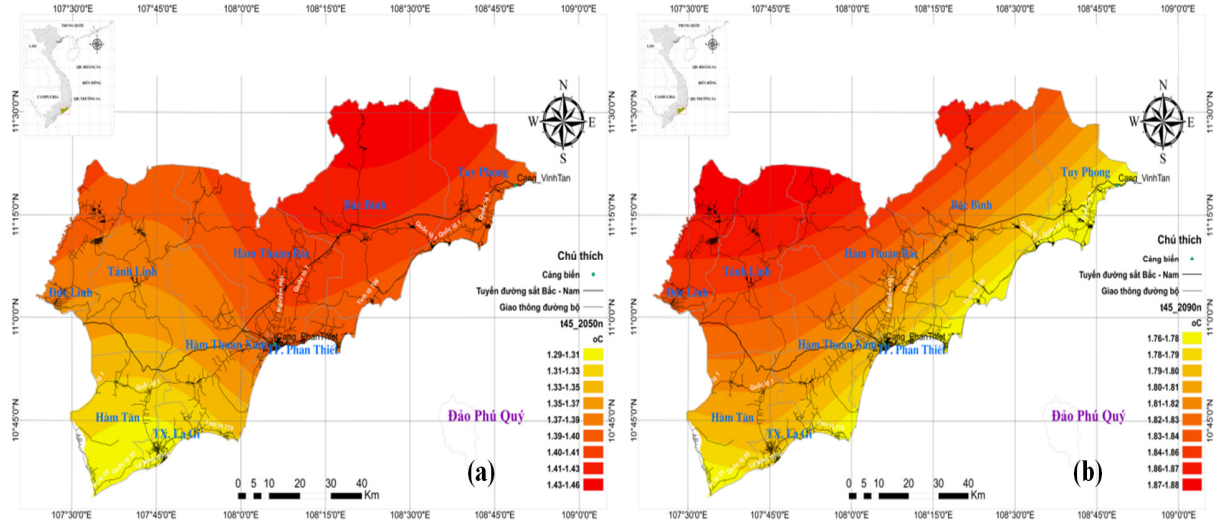

Figure 1. Map of temperature variation under the RCP4.5 scenario for the period: a) mid–21st century; b) the end of the 21st century.

Table 2. Temperature variation at some traffic routes.

Area	Increasing Temperature variation (°C)		
1. Road location			
	Location	Mid–21st century	End of 21st century
Phan Thiet	DT.719 (Tien Thanh, Tien Loi)	1.35–1.39	1.77–1.81
	DT.706B (Phu Hai, Ham Tien)	1.39–1.40	1.79–1.80
La Gi	National Road 55 (Tan Phuoc, Tan Thien, Tan An)	1.29–1.30	1.78–1.80
Duc Linh	DT.720, Ton Duc Thang, Cao Thang (Vo Xu)	1.38–1.39	1.85–1.87
Tanh Linh	DT.710, ĐT.720 (Lac Tanh)	1.36–1.38	1.83–1.86
Ham Tan	National Road 55(Tan Xuan, Tan Ha, Song Phan, Tan Nghia	1.29–1.35	1.79–1.82
Ham Thuan Nam	DT.712 (Tan Thuan, Thuan Nam), DT 719 (Tan Thuan, Tan Thanh)	1.32–1.35	1.77–1.80
Ham Thuan Bac	National Road 1 (Hoa Thang, Ham Duc, Hong Son, Hong Liem, Phu Long)	1.39–1.42	1.79–1.82
Bac Binh	National Road 1 (Binh Tan, Song Binh, Phan Thanh, Phan Hiep, Luong Son, Phan Ri Thanh)	1.39–1.43	1.77–1.83
Tuy Phong	National Road 1 (Vinh Tan, Vinh, Phuoc The, Phu Lac, Binh Thanh, Chi Cong, Hoa Minh, Lien Huong)	1.39–1.40	1.79–1.79

Area		Increasing Temperature variation (°C)	
2. North–South Railway			
Phan Thiet	Phan Thiet City	1.39–1.40	1.80–1.81
Tanh Linh	Gia Huynh, Suoi Kiet	1.35–1.36	1.82–1.84
Ham Tan	Tan Phuc, Song Phan	1.30–1.35	1.81–1.82
Ham Thuan Nam	Tan Lap, Ham Cuong, Ham Kiem	1.32–1.39	1.80–1.83
Ham Thuan Bac	Ham Hiep, Ham Liem, Ham Chinh, Hong Son, Hong Liem, Ma Lam	1.38–1.42	1.79–1.82
Bac Binh	Phan Hoa, Phan Hiep, Hai Ninh, Phan Thanh, Song Binh, Song Luy, Binh Tan, Luong Son	1.39–1.43	1.77–1.89
Tuy Phong	Phong Phu, Phu Lac, Vinh Hai, Vinh Tan	1.39–1.41	1.79–1.80
3. Areas adjacent to the coast			
Phan Thiet	Phan Thiet Port	1.39–1.40	1.80–1.81
La Gi	Lagi Port	1.29–1.30	1.78–1.79
Tuy Phong	Vinh Tan Port, Phan Ri Cua Port	1.39–1.41	1.79–1.80

3.2. Impacts of the increasing rainfall

According to the RCP 4.5 scenario, rainfall in the roads located in the study area increases from 8.5%–14% in the middle of the 21st century and 9.5%–21.6% at the end of the 21st century. The increased rainfall disrupts traffic, delays construction activities, and weakens or washes away soil and leads to overload for the supporting sewer systems. The North–South railway passing through the province is also affected by the increase in rainfall. Heavy rains can delay and disrupt trains, cause risks to the drifting and damage to the track and risk to the safety of the devices. In the middle of the century, rainfall in the areas of Phan Thiet port, Lagi fishing port, Vinh Tan port has an increase from 8.9% to 13.7% and an increase from 9.5% to 21.3% by the end of the century. The impacts of temperature variation are detailed as show in Figure 2 and Table 3.

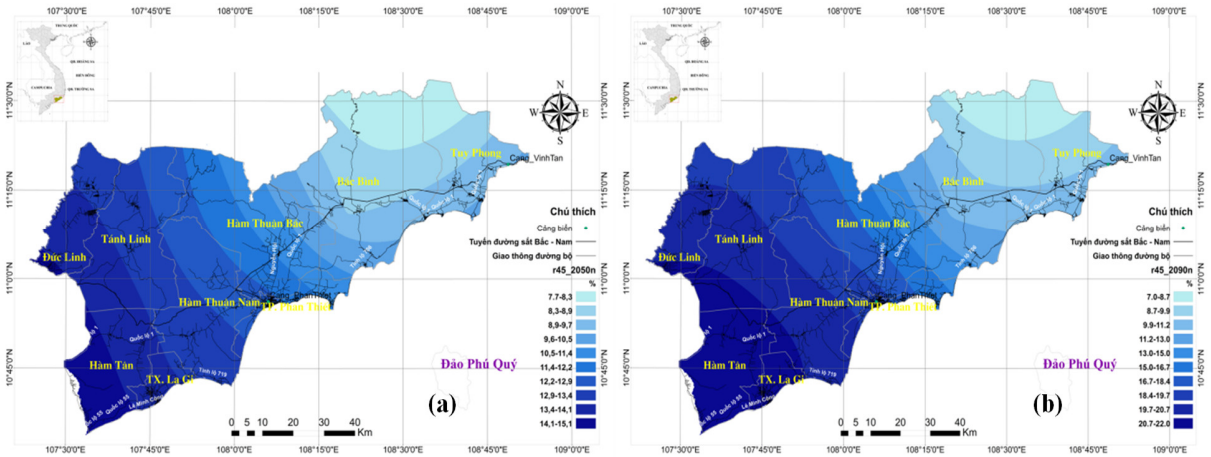

Figure 2. Rainfall verification map under the RCP4.5 scenario for the period: a) mid–21st century; b) the end of the 21st century.

Table 3. Temperature variation at some traffic points.

Area	Increasing Rainfall (%)		
1. Road			
	Location	Mid–21st century	End of 21st century
Phan Thiet	DT.719 (Tien Thanh, Tien Loi)	12.5–13.0	19.3–20.1
	DT.706B (Phu Hai, Ham Tien)	11.3–12.2	16.5–17.9
La Gi	National Road 55 (Tan Phuoc, Tan Thien, Tan An)	13.5–14	21.9–21.5
Duc Linh	DT.720, Ton Duc Thang, Cao Thang (Vo Xu)	13.4–13.8	19.7–20.3
Tanh Linh	DT.710, ĐT.720 (Lac Tanh)	12.9–13.4	19.6–21.2
Ham Tan	National Road 55(Tan Xuan, Tan Ha, Song Phan, Tan Nghia	13.4–13.9	20.8–21.6
Ham Thuan Nam	DT.712 (Tan Thuan, Thuan Nam), DT 719 (Tan Thuan, Tan Thanh)	13.1–13.5	20.2–21.1
Ham Thuan Bac	National Road 1 (Hoa Thang, Ham Duc, Hong Son, Hong Liem, Phu Long)	9.5–12.7	12.1–19.3
Bac Binh	National Road 1 (Binh Tan, Song Binh, Phan Thanh, Phan Hiep, Luong Son, Phan Ri Thanh)	8.5–9.4	9.6–15.2
Tuy Phong	National Road 1 (Vinh Tân,Vinh Hao, Phuoc The, Phu Lac, Binh Thanh, Chi Cong, Hoa Minh, Lien Huong)	9.2–9.8	9.5–11.2
2. North–South Railway			
Phan Thiet	Phan Thiet City	12.2–12.5	17.9–19.3
Tanh Linh	Gia Huynh, Suoi Kiet	12.9–13.4	19.6–21.2
Bac Binh	Phan Hoa, Phan Hiep, Hai Ninh, Phan Thanh, Song Binh, Song Luy, Binh Tan, Luong Son	8.5–9.4	9.6–15.2
Ham Tan	Tan Phuc, Song Phan	13.4–13.9	20.8–21.2
Ham Thuan Bac	Ham Hiep, Ham Liem, Ham Chinh, Hong Son, Hong Liem, Ma Lam	9.5–12.7	12.1–19.3
Ham Thuan Nam	Tan Lap, Ham Cuong, Ham Kiem	12.5–13.5	18.1–21.1
Tuy Phong	Phong Phu, Phu Lac,Vinh Hai,Vinh Tan	8.9–9.8	9.5–10.1
3. Areas adjacent to the coast			
Phan Thiet	Phan Thiet Port	12.5–12.8	17.9–19.3
La Gi	Lagi Port	13.5–13.7	21.0–21.3
Tuy Phong	Vinh Tan Port, Phan Ri Cua Port	8.9 –9.2	9.5 – 10.1

4. Conclusion

The climate change will pose impacts on transport sector in Binh Thuan Province inclusive of traffic routes (roads, railways, and waterways), areas adjacent to the coast and embankments in Binh Thuan province. The temperature rise poses risks of deforming on the railway, causing distortion for rail signals and deduction in life cycle of train and related devices. The base–temperature rise and high value of temperature shall be one of the factors causing risks of concrete cracks, cracking and rutting of wheel tracks of asphalt pavement, reducing the service life of the building and increasing costs for service and maintenance. The increase in rainfall can lead to the delay and interruption of transport routes, landslides, and leave debris on the road causing danger during transportation. Heavy rain may cause the risk of flooding, directly affecting traffic works, increasing erosion of road surface and roadbed. In addition, traffic routes, train stations, bus stations and railway lines may also be affected causing impacts on the travel process.

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Conflicts of Interest: The authors declare that there are no conflict of interest.

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