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Cost and impact analysis of sea level rise on coastal Vietnam

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Abstract: The Development under Climate Change research effort provides a basis for determining quantitative impacts on infrastructure from climate change. This paper provides results of an analysis of sea level rise impacts on road infrastructure in Vietnam. The study utilizes a quantitative approach for determining these impacts through engineering-based models that estimate the impact of sea level rises on road infrastructure. Through this approach, the cost impact of sea level rises on the coastal regions of Vietnam are presented.

Keywords: Infrastructure, climate, vulnerability, resilience, adaptation
JEL classification: Q54, O44, O55

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1 Introduction

Sea level rise (SLR) is an important component of understanding the effects of climate change on infrastructure in countries with coastal areas. Projections on the amount of SLR that will occur in a specific region are uncertain and projections vary widely. Some recent studies have predicted a future SLR higher than 1 m by 2100 (Nicholls and Cazenave 2010). The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change published in 2007 predicts an average rise of 60 cm by 2100 (Solomon et al. 2007). However, it is widely believed that the SLR will not be uniform throughout the world and certain areas will be affected at much greater levels than others (Neumann et al. 2000).

Although uncertainty exists in SLR models, SLR is an important consideration for climate change impacts due to the large populations that exist in low-elevation coastal areas. It is estimated that these areas contain about 10 per cent of the world's population (Nicholls and Cazenave 2010). Developing countries are particularly vulnerable to SLR due to the high concentration of population, industry, and rapidly growing urban areas that exist along the coasts in these countries (Kamal-Chaoui and Robert 2009). Southeast Asia and Africa have been identified as areas with great concern about projected SLR, particularly from models that project more extreme global SLR. Additionally, island states face unique issues; in some cases potential submersion of entire states may be projected.

The concern about SLR for these regions is the potential for SLR to affect economies and populations in dramatic ways. Industries that operate in low-lying coastal areas, including tourism, settlement, shipping, commercial and recreational fishing, and agriculture face pressures and consequences from SLR (Neumann et al. 2000). Additionally, road infrastructure is an important component when considering the impacts of SLR. Because infrastructure investment represents an important aspect of national budgets and economic development, and the life cycle of many roads is 20 years or greater, it is important to consider climate change for current and future plans. For low-lying coastal areas, specifically those in developing countries, making decisions about infrastructure with a forward-looking perspective is a key to mitigating potentially costly impacts from SLR.

While SLR presents a threat to many areas, adaptation and mitigation options exist. The opportunity exists to increase the understanding of sea level change and the potential impact on coastal infrastructure. According to Nicholls and Cazenave (2010), 'We must choose between protection, accommodation, and planned retreat adaptation options. This choice is both technical and sociopolitical, addressing which measures are desirable, affordable, and sustainable in the long term. Adaptation remains a major uncertainty concerning the actual impacts of SLR'. This paper introduces the first element of this understanding in a specific context and on a specific infrastructure element. Using Vietnam as the context, this paper examines the potential impact of SLR on road infrastructure in coastal areas of Vietnam.

2 The current study

The current study examines the potential impact of SLR on the coastal zones of Vietnam. The study is one part of a larger focus on the effects of climate change on Vietnam in terms of both infrastructure and economic impacts. The focus of the SLR analysis is to determine based on current sea level data what the potential damage will be to coastal road infrastructure. The study focuses on damage as the cost of replacing current road infrastructure. The underlying concept is that roads affected by sea level inundation will need to be replaced by infrastructure located further inland from the affected areas. The study does not incorporate adaptation options such as coastal defences. Rather, the emphasis is on potential loss of road infrastructure and the costs associated with replacing this infrastructure.

The following sections detail the methodology used to conduct the study and the results obtained from the analysis. The results are placed in the context of individual provinces to allow for geographic comparison of potential damage.

3 SLR methodology

The methodology adopted for the current study focuses on combining existing cost existing cost data for replacing roads with a determination of how many kilometres of road will be affected in each province. Achieving this determination requires a combination of GIS (Geographic Information System) analysis, SLR predictions, and cost information within the context of Vietnam and its geography and infrastructure.

3.1 Road inventory allocation

For this study, SLR impact was applied to nine classifications of road infrastructure: primary, secondary, and tertiary classifications of paved, gravel, and unpaved road types. A uniform engineering design standard was used for each road type to establish a common baseline for each road category. A uniform costing measure is applied per kilometre to each road type to allocate standard construction costs for replacement of inundated roads (Table 1). The determination of the location of the existing inventory is accomplished in one of two processes. Where possible, existing roadstock data for each province have been obtained from government data. However, when only national roadstock information is available, the inventory is allocated to each province based on a geographic allocation algorithm previously developed by the authors for climate studies. In this process, which was employed extensively in the Vietnam study, the percentage of total land area and population that each province contains is used as the basis for the road allocation. Specifically, the national roadstock is allocated based on the percentage of area and population that a specific province has in relation to the national total. The allocation assumes that road inventory will be proportionally located based on area and population distributions. For analysis purposes, it is assumed that once the roadstock is allocated to a province, the roadstock is evenly distributed throughout the province. Appendix A contains a detailed breakdown of the kilometre estimates of each road type for each province.

Table 1: SLR costs

Costs of new roads			
	Paved (US$)	Gravel (US$)	Unpaved (US$)
Primary	500,000	226,000	128,000
Secondary	150,000	135,000	75,000
Tertiary	70,000	75,150	41,750

Source: Authors' calculations.

3.2 GIS interface

SLR information is publicly available in GIS format. However, to ensure that geographic application of the data is completed accurately, both the SLR and provincial mapping of the country are translated into a standard grid system based on latitude and longitude. In terms of the current study, Climate Research Unit (CRU) grid cells of 0.5 degree latitude by 0.5 degree longitude (approximately 250 km^2 area) are the basis of this data translation. The CRU dataset is an open source, global land surface time series of historical weather data. The information used in this analysis is CRU TS 2.1 (Climate Research Unit Time Series Version 2.1). Several data parameters are included; this analysis focuses on the reported precipitation and maximum temperature (Mitchell 2004). The CRU data has an ArcGIS interface to allow for analysis with other GIS maps. This interface allowed the CRU grids to be used as the basis for combining the provincial mapping data with the projected SLR information.

The basis of this translation is through an overlay process that translates the geographic information for each province into grid cells. Specifically, the provinces are allocated to grid cells by percentage of geographic area that corresponds to specific CRU grid cells. For example, Administrative Area 1 may be allocated geographically between grid cells A and B at 30 per cent and 70 per cent, respectively. In this case, the province is recorded as having proportional area allocations in each grid location. This allocation is done using the ArcGIS Intersect function to standardize the process. In a region where detailed road location information is not available, the roadstock is then uniformly distributed at the same ratio of 30 per cent and 70 per cent, respectively, as the basis for the impact analysis. The result of this allocation process is that the kilometres of road in each province are allocated proportionally at a grid cell level. This allocation can now be combined with the sea level data to determine impacts in a specific geographic location.

3.3 SLR analysis

To analyse the impact of a sea level rise, a dataset is used from the Center for Remote Sensing of Ice Sheets at the University of Kansas. This dataset provides information for a one metre or greater projected SLR throughout the context of the Vietnam study. The data were provided in a GIS map that the team intersected with the CRU grid cell information to obtain a consistent information base. The SLR information was then used to estimate the percentage of each grid cell that would be 'inundated'—land completely covered by more than one metre of SLR. Where inundation was projected, it was assumed that all nine types of roadstock located in an inundated area would be destroyed.

To estimate the amount of roadstock destroyed by a sea level rise, a uniform distribution of roads, as described above, is assumed. The SLR is also assumed to be a uniform distribution. For example, if 50 per cent of a CRU grid cell is projected to be inundated by SLR, 50 per cent of the roadstock in the cell is estimated to be destroyed. If the CRU grid cell contains roadstock from more than one provincial level, the 50 per cent destruction is then applied to the roadstock of each province equally. In this example, if CRU grid cell A contains 40 per cent of Province 1 and 60 per cent of Province 2 in terms of area, and 50 per cent of the CRU grid cell is estimated to be inundated, then 50 per cent of the roadstock from Province 1 and 50 per cent of the roadstock from Province 2 that is located in that grid cell is destroyed. The specific kilometres of road affected will correspond to the initial roadstock allocation that has then been overlaid and downscaled from the national to the provincial level, and then to the corresponding CRU grid cells for each road.

3.4 Cost determination

Once the kilometres of roads inundated are determined for each grid cell, the determination of costs for replacing these roads is performed. The costs for replacement are based on individual determinations in each grid cell for each road type. In the case of SLR, current costing analysis is carried out using the cost to build a new kilometre of road of each type, since sea level inundation projects a total loss of road inventory. Other adaptation options are not explored with this analysis. The totals for each cell are then combined at a provincial level to provide a total road impact cost.

Table 2 provides a detailed illustration depicting costing and summation of provincial damage. As illustrated, an analysis of the impact of one metre of SLR on the existing roadstock inventory of Province 1 and Province 2 is shown. The roadstock inventory is broken down by type and allocated to the corresponding CRU grid cell. The SLR projected in that grid is applied to the roadstock inventory and damages are assessed. The far right columns show the total kilometres and total cost impact of the projected SLR: 21.15 km and US$3 million, respectively, for Province 1 and 100 km and US$12.4 million for Province 2. These are examples only; full datasets can be seen in Appendix A.

4 Study results

The study results presented here are based on a one-metre SLR, which is the basis of the inundation data adopted for the study. A sea level rise of one metre will affect the existing estimated road infrastructure in Vietnam to the extent of 19,000 km of road infrastructure inundated and destroyed; just under 12 per cent of existing road infrastructure. This is a cost of approximately US$2.09 billion to replace the inundated infrastructure (Table 3). This is for all road types. The projected SLR is distributed unevenly, with the majority of damage affecting coastal regions in the southern part of the country. There are several provinces where a complete inundation is projected, resulting in a loss of at or near 100 per cent. These include Bac Lieu, Hau Giang, Soc Trang, Tra Vinh and Ca Mau. The ten most affected provinces are located in the Mekong River Delta region and have an average of 77 per cent of road infrastructure destroyed—a total of nearly 15,200 km. Figures 1-3 illustrate the percentage of road infrastructure damaged and total cost estimates at both regional and provincial levels. A full table of approximated damages can be seen in Appendix A.

Table 2: National-level results for one-metre SLR

	Total % damaged	Total road damage	Paved primary	Paved secondary	Paved tertiary	Gravel tertiary	Unpaved tertiary
Total damage (km)	12	19,142	1,621	3,775	3,719	9,024	1,003
Total damage (US$ million)	-	2,089	810	566	260	377	75

Province	CRU grid cell	% of area in CRU cell	Road type	km of roads in CRU grid cell	% SLR damage	Total km damaged	Total cost (US$)	Province: Total km damaged	Province: Total cost (US$)
1	A	40	Paved primary	20	5	1	500,000	21.15	3,009,173
1	A	40	Paved secondary	30	5	1.5	225,000		
1	A	40	Paved tertiary	0	5	0	-		
1	A	40	Gravel primary	0	5	0	-		
1	A	40	Gravel secondary	50	5	2.5	337,500		
1	A	40	Gravel tertiary	10	5	0.5	37,575		
1	A	40	Unpaved primary	0	5	0	-		
1	A	40	Unpaved secondary	0	5	0			
1	A	40	Unpaved tertiary	70	5	3.5	146,125		
1	B	60	Paved primary	30	5	1.5	750,000		
1	B	60	Paved secondary	45	5	2.25	337,500		
1	B	60	Paved tertiary	0	5	0	-		
1	B	60	Gravel primary	0	5	0	-		
1	B	60	Gravel secondary	65	5	3.25	438,750		
1	B	60	Gravel tertiary	13	5	0.65	48,848		
1	B	60	Unpaved primary	0	5	0	-		
1	B	60	Unpaved secondary	0	5	0	-		
1	B	60	Unpaved tertiary	90	5	4.5	187,875		
2	A	10	Paved primary	5	20	1	500,000	100	12,373,000
2	A	10	Paved secondary	5	20	1	150,000		
2	A	10	Paved tertiary	0	20	0	-		
2	A	10	Gravel primary	0	20	0	-		
2	A	10	Gravel secondary	10	20	2	270,000		
2	A	10	Gravel tertiary	10	20	2	150,300		
2	A	10	Unpaved primary	0	20	0	-		
2	A	10	Unpaved secondary	0	20	0	-		
2	A	10	Unpaved tertiary	20	20	4	167,000		
2	C	90	Paved primary	45	20	9	4,500,000		
2	C	90	Paved secondary	45	20	9	1,350,000		
2	C	90	Paved tertiary	0	20	0	-		
2	C	90	Gravel primary	0	20	0	-		
2	C	90	Gravel secondary	90	20	18	2,430,000		
2	C	90	Gravel tertiary	90	20	18	1,352,700		
2	C	90	Unpaved primary	0	20	0	-		
2	C	90	Unpaved secondary	0	20	0	-		
2	C	90	Unpaved tertiary	180	20	36	1,503,000		

Source: Authors' calculations.

4.1 Mekong River Delta region

As stated above, the Mekong River Delta region incurs the greatest damage from a one metre SLR. The Mekong River Delta region includes 13 provinces with damage estimates ranging from 14 per cent to 99.5 per cent. The Mekong River Delta is located in the southernmost part of Vietnam and the majority of the land area is located at less than three metres above sea level, making inundation from SLR a serious risk in terms of population relocation and total loss of infrastructure, agriculture, and other industries located in these provinces. Seasonal flooding and inundation from typhoons and natural weather events are a current concern that may be exacerbated by SLR. For the infrastructure to be rebuilt, the cost is estimated at US$1.6 billion—approximately 77 per cent of the total SLR cost for all of Vietnam. The provinces of Bac Lieu, Hau Giang, Soc Trang, Tra Vinh, and Ca Mau can anticipate a potential damage rate of 96-100 per cent of their current infrastructure. Therefore, a one-metre SLR in these provinces could translate into damage to all or almost all of the roads located in these regions.

4.2 Southeast and Red River Delta regions

The regions with the greatest impact following the Mekong River Delta are the southeast and Red River Delta areas. These regions have an average inundation of 6 per cent, but with individual provinces having inundation of 0-21 per cent. The coastal provinces of Ho Chi Minh and Nam Dinh have inundations of 20 per cent and 21 per cent, respectively, with costs of approximately US$165 million and US$46 million, respectively. The difference in total cost (US$119 million) is much greater than the 1 per cent inundation difference would suggest. This is accounted for in Ho Chi Minh's large existing roadstock of 6,800 km, compared with Nam Dinh's roadstock of 2,000 km.

The percentage effects of SLR on these regions may be small, but because of the densely populated Red River Delta region and urban areas surrounding Ho Chi Minh, the impacts from loss of transport and access may have economic and other consequences. Adaptation issues should be considered for each province based on the redundancy and importance of the networks in areas that are expected to be inundated.

Several provinces in these areas experience no impact from SLR. These are mainly provinces that are inland with no coastal lands and that are therefore more resilient against a rise in sea level. A full list of provinces and estimated damage levels can be seen in Appendix A.

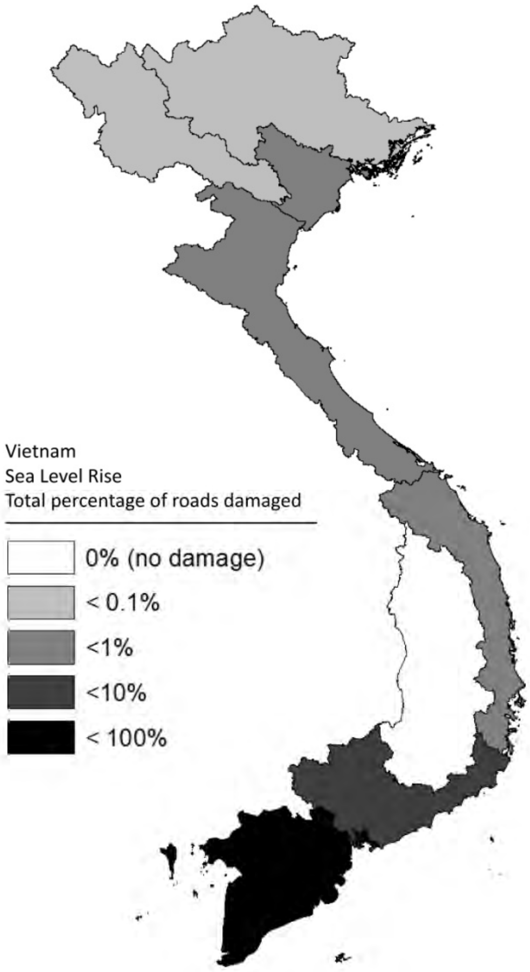
4.3 Northern central area

There is very little impact from SLR on the Northern Central area, with average provincial inundation of 0.03-1.3 per cent of total roadstock. The most expensive impacts are seen in Da Nang and Phu Yen, with costs of US$1.6 and US$2.4 million, respectively. Phu Yen has an estimated existing roadstock of over 1,900 km (44 km damaged), compared to Da Nang's roadstock estimate of 1,000 km (29 km damaged).

4.4 Other regions

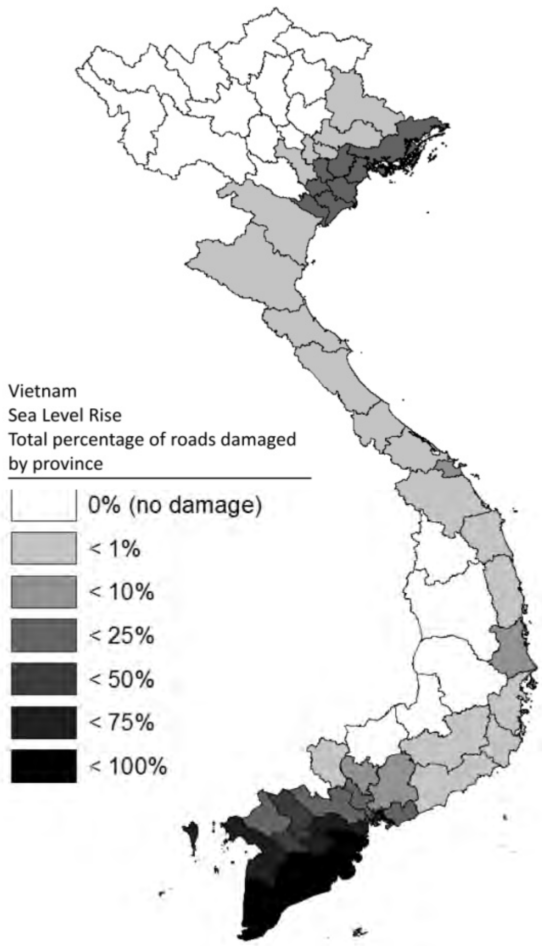
The remaining provinces show little or no impact from a projected SLR of one metre. The Central Highlands region experiences zero impact in all provinces. The Northern Midlands have a range of impacts from 0 to 1 per cent. The province of Bac Giang has the greatest impact at 0.06 per cent; a total of 3 km of roads damaged at a cost of US$162,000. The lack of effect from SLR in these regions is because they are either inland or protected from a coastal SLR by elevations and natural defences that protect against inundation.

Figure 1: Regional effects of SLR in percentage of roads damaged



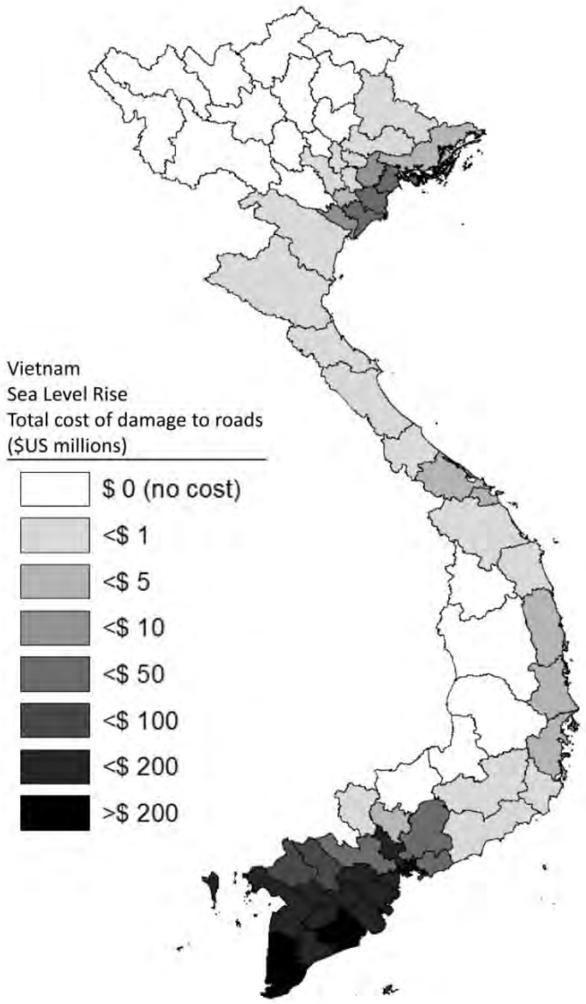
Source: Ministry of Planning and Investment (2012) and IRF (2009).

Figure 2: SLR damage by province in percentage damaged



Source: Ministry of Planning and Investment (2012) and IRF (2009).

Figure 3: SLR damage by province in US$ millions



Source: Ministry of Planning and Investment (2012) and IRF (2009).

5 Conclusion

With over 3,400 km of coastline, Vietnam is susceptible to SLR impacts along the entire eastern side of the nation. The terrain is: low, flat delta in the south and north; central highlands; hilly and mountainous in the far north and northwest. As documented in the study, this geography creates a scenario where extensive damage to road infrastructure may occur if a one metre SLR is realized. The potential cost of damage from inundation in this scenario is over US$2 billion. However, this damage is not equal throughout the country. Differences in infrastructure density and coastal vulnerability will affect local damage estimates.

The result of this study indicates that further study should be considered at a local level in districts where severe damage from inundation is predicted. Adaptation options such as coastal defences, road hardening, and road relocation should be examined. However, consideration should be given to when a sea level rise is expected to occur and whether some infrastructure may be needed if a neighbouring land area is inundated. Each of these issues may be considered at a more detailed level in subsequent studies undertaken at regional levels.

References

IRF (2009) *World Road Statistics 2009*. Geneva: International Road Federation.

Kamal-Chaoui, L., and A. Robert (eds) (2009). 'Competitive Cities and Climate Change'. OECD Regional Development Working Papers 2. Paris: OECD.

Ministry of Planning and Investment (2012). 'Electronic Data on Roadstocks' Hanoi: Ministry of Planning and Investment, Central Institute for Economic Management.

Mitchell, T.D. (2004). 'An Improved Method of Constructing a Database of Monthly Climate Observations and Associated High Resolution Grids'. Tyndall Centre for Climate Change Research. Available at: www.cru.uea.ac.uk/~timm/grid/CRU_TS_2_1.html (accessed 1 December 2011).

Neumann, J.E., G. Yohe, R. Nicholls, and M. Manion (2000). *Sea-Level Rise and Global Climate Change: A Review of Impacts to U.S. Coasts*. Arlington, VA: Pew Center on Global Climate Change.

Nicholls, R.J., and A. Cazenave (2010). 'Sea Level Rise and its Impact on Coastal Zones'. *Science*, 328(5985): 1517-20. Available at: www.sciencemag.org/content/328/5985/1517.full.html#ref-1 (accessed 30 October 2014).

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds) (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, NY: Cambridge University Press.

Appendix A

Table A1: Estimated roadstock allocation

Region	Province	Population 2009 estimates	Area (km) 2009 estimates	Estimated road allocation (% of total)	Paved primary	Paved secondary	Paved tertiary	Unpaved tertiary	Gravel tertiary
Central Highlands	Gia Lai	1,272,792	15,537	3.1	419	975	961	2331	259
	Kon Tum	430,037	9,691	1.7	232	541	533	1294	144
	Lam Dong	1,186,786	9,772	2.2	294	684	674	1636	182
	Dac Lac	1,728,380	13,125	3.0	405	944	930	2256	251
	Dac Nong	489,442	6,516	1.3	172	401	395	958	106
Mekong River Delta	An Giang	2,144,772	3,537	1.8	242	563	555	1347	150
	Ben Tre	1,254,589	2,360	1.1	147	343	338	821	91
	Ca Mau	1,205,108	5,332	1.5	204	476	469	1138	126
	Can Tho	1,187,089	1,402	0.9	122	285	281	682	76
	Dong Thap	1,665,420	3,375	1.5	201	467	460	1117	124
	Kien Giang	1,683,149	6,346	1.9	263	612	603	1464	163
	Long An	1,436,914	4,494	1.5	206	479	472	1144	127
	Soc Trang	1,289,441	3,312	1.3	170	395	389	945	105
	Tien Giang	1,670,216	2,484	1.3	183	426	419	1018	113
	Bac Lieu	856,250	2,502	0.9	119	277	273	662	74
	Hau Giang	756,625	1,601	0.7	93	216	212	515	57
	Tra Vinh	1,000,933	2,295	0.9	126	294	289	702	78
	Vinh Long	1,028,365	1,479	0.8	112	260	256	621	69
Northern Central area and Central Coastal area	Binh Thuan	1,169,450	7,810	1.9	252	588	579	1405	156

Khanh Hoa	1,156,903	5,218	1.5	198	462	455	1104	123
Nghe An	2,913,055	16,491	4.2	568	1323	1303	3161	351
Phu Yen	861,993	5,061	1.3	172	400	394	956	106
Quang Tri	597,985	4,747	1.1	144	336	331	804	89
Thanh Hoa	3,400,239	11,133	3.7	497	1157	1139	2765	307
Thua Thien-Hue	1,087,579	5,063	1.4	190	442	435	1055	117
Binh Dinh	1,485,943	6,040	1.8	241	561	553	1342	149
Da Nang	887,069	1,283	0.7	96	224	221	536	60
Ha Tinh	1,227,554	6,026	1.6	220	513	506	1227	136

Northern Central area and Central Coastal area	Ninh Thuan	564,129	3,358	0.8	113	264	260	631	70
	Quang Binh	846,924	8,065	1.7	232	540	532	1292	144
	Quang Nam	1,419,503	10,438	2.4	326	759	748	1814	202
	Quang Ngai	1,217,159	5,153	1.5	202	470	463	1123	125
Northern Midlands and mountain areas	Bac Giang	1,555,720	3,828	1.5	201	469	462	1121	125
	Cao Bang	510,884	6,725	1.3	178	415	409	991	110
	Dien Bien	491,046	9,563	1.7	235	546	538	1306	145
	Ha Giang	724,353	7,946	1.6	220	512	505	1224	136
	Lai Chau	370,135	9,112	1.6	216	503	495	1201	133
	Lang Son	731,887	8,324	1.7	228	532	524	1271	141
	Lao Cai	613,075	6,384	1.3	179	417	411	997	111
	Phu Tho	1,313,926	3,532	1.3	176	410	404	981	109

	Son La	1,080,641	14,174	2.8	376	875	862	2091	232
	Bac Can	294,660	4,859	0.9	123	286	282	683	76
	Hoa Binh	786,964	4,595	1.2	156	364	359	870	97
	Thai Nguyen	1,124,786	3,526	1.2	161	375	370	897	100
	Tuyen Quang	725,467	5,870	1.3	177	413	407	988	110
	Yen Bai	740,905	6,899	1.5	200	465	458	1112	124
Red River Delta	Hung Yen	1,128,702	923	0.8	108	252	248	602	67
	Nam Dinh	1,825,771	1,653	1.3	178	415	409	991	110
	Quang Ninh	1,144,381	6,099	1.6	215	501	494	1199	133
	Bac Ninh	1,024,151	823	0.7	98	228	224	544	60
	Hai Duong	1,703,492	1,650	1.2	168	392	386	937	104
	Haiphong	1,837,302	1,522	1.3	176	411	405	982	109
	Ha Nam	785,057	860	0.6	80	185	183	443	49
	Hanoi	6,448,837	3,345	4.3	578	1346	1326	3218	358
	Ninh Binh	898,459	1,389	0.7	99	232	228	554	61
	Thai Binh	1,780,954	1,567	1.3	173	402	396	962	107
	Vinh Phuc	1,000,838	1,232	0.8	104	243	239	581	65
Southeast	Binh Phuoc	874,961	6,875	1.5	210	489	482	1169	130
	Dong Nai	2,483,211	5,903	2.3	317	738	727	1765	196
	Tay Ninh	1,066,402	4,049	1.2	167	389	384	931	103
	Ba Ria-Vung Tau	994,837	1,987	0.9	119	278	274	664	74
	Binh Duong	1,482,636	2,695	1.3	172	401	395	959	107

	Ho Chi Minh	7,123,340	2,096	4.5	606	1411	1390	3372	375
Totals		85,789,573	331,051	100.0	13554	31575	31105	75470	8385

Note: According to published data all primary and secondary roads are 'paved' (IRF 2009). Therefore, all calculations for gravel and paved roads were calculated at the cost of tertiary roads.

Source: Ministry of Planning and Investment (2012) and IRF (2009).

Table A2: Estimated SLR damage

Region	Province	Total damage	Total damage	Paved	Paved	Paved	Gravel	Unpaved
		(%)	(km)	Primary	Secondary	Tertiary	Tertiary	Tertiary
Mekong River Delta	Bac Lieu	99.53	1397.3	118.3	275.6	271.5	73.2	658.7
	Hau Giang	99.47	1087.3	92.1	214.4	211.3	56.9	512.6
	Soc Trang	99.17	1987.3	168.3	392.0	386.1	104.1	936.9
	Tra Vinh	97.70	1454.5	123.1	286.9	282.6	76.2	685.7
	Ca Mau	96.78	2335.8	197.8	460.7	453.8	122.3	1101.2
	Ben Tre	84.93	1478.9	125.2	291.7	287.3	77.5	697.2
	Vinh Long	71.99	948.2	80.3	187.0	184.2	49.7	447.0
	Tien Giang	71.06	1534.1	129.9	302.6	298.1	80.4	723.2
	Kien Giang	51.88	1610.9	136.4	317.7	313.0	84.4	759.4

	Can Tho	45.20	653.8	55.4	129.0	127.0	34.2	308.2
	Dong Thap	29.40	696.7	59.0	137.4	135.4	36.5	328.4
Southeast	Ho Chi Minh	21.17	1514.1	128.2	298.6	294.2	79.3	713.8
Red River Delta	Nam Dinh	20.19	424.7	36.0	83.8	82.5	22.2	200.2
Mekong River Delta	An Giang	16.28	465.1	39.4	91.7	90.4	24.4	219.2
Red River Delta	Thai Binh	15.11	308.3	26.1	60.8	59.9	16.1	145.3
	Haiphong	13.68	284.8	24.1	56.2	55.3	14.9	134.3
Mekong River Delta	Long An	13.53	328.5	27.8	64.8	63.8	17.2	154.9
Southeast	Ba Ria-Vung Tau	9.46	133.3	11.3	26.3	25.9	7.0	62.8
Red River Delta	Ninh Binh	5.45	64.0	5.4	12.6	12.4	3.4	30.2
	Hai Duong	3.47	68.9	5.8	13.6	13.4	3.6	32.5
	Ha Nam	2.99	28.1	2.4	5.5	5.5	1.5	13.2

Southeast	Dong Nai	2.89	108.1	9.2	21.3	21.0	5.7	50.9
Red River Delta	Quang Ninh	1.26	32.1	2.7	6.3	6.2	1.7	15.2
Northern Central area and Central Coastal area	Da Nang	1.26	14.3	1.2	2.8	2.8	0.8	6.8
	Phu Yen	1.09	22.1	1.9	4.4	4.3	1.2	10.4
Southeast	Binh Duong	1.07	21.7	1.8	4.3	4.2	1.1	10.3
Northern Central area and Central Coastal area	Binh Dinh	0.79	22.5	1.9	4.4	4.4	1.2	10.6
	Khanh Hoa	0.78	18.2	1.5	3.6	3.5	1.0	8.6
	Thua Thien-Hue	0.73	16.4	1.4	3.2	3.2	0.9	7.8
	Quang Tri	0.38	6.5	0.6	1.3	1.3	0.3	3.1
	Ha Tinh	0.35	9.1	0.8	1.8	1.8	0.5	4.3
	Ninh Thuan	0.30	4.1	0.3	0.8	0.8	0.2	1.9

	Quang Ngai	0.14	3.3	0.3	0.7	0.6	0.2	1.6
	Quang Nam	0.13	5.0	0.4	1.0	1.0	0.3	2.4
Red River Delta	Bac Ninh	0.11	1.3	0.1	0.3	0.2	0.1	0.6
Northern Central area and Central Coastal area	Thanh Hoa	0.10	6.1	0.5	1.2	1.2	0.3	2.9
	Binh Thuan	0.09	2.8	0.2	0.5	0.5	0.1	1.3
Southeast	Tay Ninh	0.08	1.6	0.1	0.3	0.3	0.1	0.7
Northern Midlands and mountain areas	Bac Giang	0.06	1.5	0.1	0.3	0.3	0.1	0.7
Northern Central area and Central Coastal area	Quang Binh	0.04	1.0	0.1	0.2	0.2	0.1	0.5
	Nghe An	0.03	1.7	0.1	0.3	0.3	0.1	0.8
Northern Midlands and mountain areas	Lang Son	0.01	0.3	0.0	0.1	0.1	0.0	0.1
Central Highlands	Lam Dong	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Red River Delta	Hanoi	0.00	0.0	0.0	0.0	0.0	0.0	0.0

Northern Midlands and mountain areas	Bac Can	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Southeast	Binh Phuoc	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Northern Midlands and mountain areas	Cao Bang	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Central Highlands	Dac Lac	0.00	0.0	0.0	0.0	0.0	0.0	0.0
	Dac Nong	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Northern Midlands and mountain areas	Dien Bien	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Central Highlands	Gia Lai	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Northern Midlands and mountain areas	Ha Giang	0.00	0.0	0.0	0.0	0.0	0.0	0.0
	Hoa Binh	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Central Highlands	Kon Tum	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Northern Midlands and mountain areas	Lai Chau	0.00	0.0	0.0	0.0	0.0	0.0	0.0
	Lao Cai	0.00	0.0	0.0	0.0	0.0	0.0	0.0

	Phu Tho	0.00	0.0	0.0	0.0	0.0	0.0	0.0
	Son La	0.00	0.0	0.0	0.0	0.0	0.0	0.0
	Thai Nguyen	0.00	0.0	0.0	0.0	0.0	0.0	0.0
	Tuyen Quang	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Red River Delta	Vinh Phuc	0.00	0.0	0.0	0.0	0.0	0.0	0.0
Northern Midlands and mountain areas	Yen Bai	0.00	0.0	0.0	0.0	0.0	0.0	0.0

Note: Table is ordered from greatest SLR damage to least.

Source: Ministry of Planning and Investment (2012) and IRF (2009).