Strengthening Research Capacity:

An Holistic Approach to Infrastructure Planning in Developing Countries

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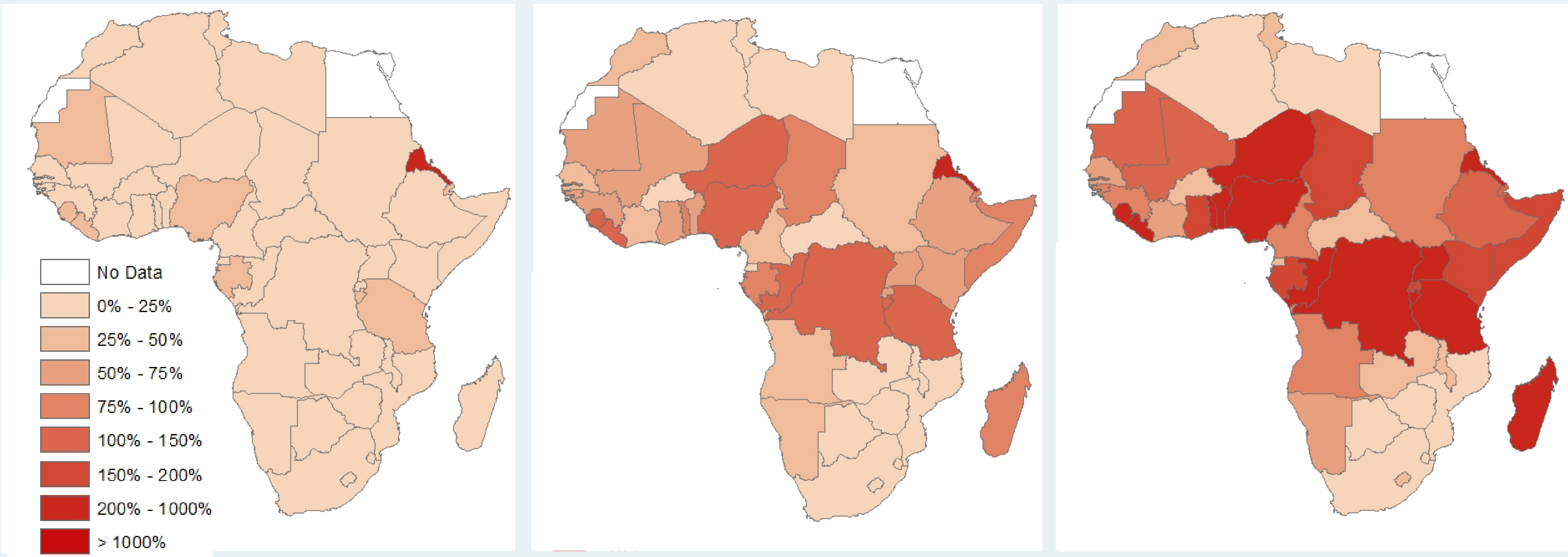
Climate Change & Roads

2020 ***2060*** ***2100***



Understanding, Evaluating, and Analyzing the impacts - and adaptation options - of climate change on infrastructure

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Background – Why Roads?

Roads & Development

- 2 km access to **all-season road**

- Lower vehicle operating costs, reduced travel time, increased **access for services such as education and healthcare**

- Higher economic return for (perishable) goods and travel to markets, **market knowledge** allows for more even price distribution

- "**Poverty Trap**" - Critical mass of infrastructure

Introduction

Infrastructure Planning & Support System (IPSS)

- Analysis climate change impact on **road and building infrastructure** by year through 2100
- Developed originally for Mozambique; extended for work in Vietnam, China, South Korea, and Japan
- Current efforts in training and capacity-building for policy makers in Ghana and South Africa

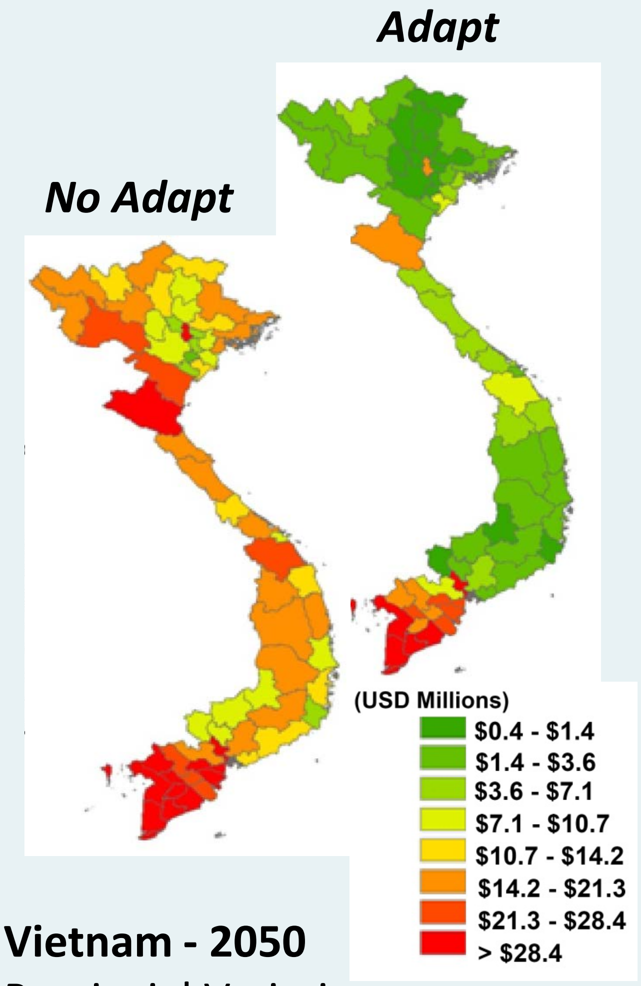
- IPSS is created out of original concepts developed for the Economics of Adaptation to Climate Change (EACC) Project under the World Bank in 2009

"Analysis of Climate Change Impacts on Road Infrastructure in Developing and Developed Countries" (Chinowsky, et al) published in Engineering Project Organization Journal (2011)

Why Develop a System Like IPSS?

- Most previous work on climate change impacts on infrastructure is qualitative – lacked specific costs, damages, adaptation options

- Give policy guidance for current and future planning
  - What impacts does road infrastructure have on development?
  - Is adaptation important?



Vietnam - 2050
Provincial Variations up to *$35 million USD*

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Adapt vs. No Adapt Policy Approach

IPSS analyzes all infrastructure and climate scenarios according to policy perspectives

ADAPT	NO ADAPT
• **Forward looking** – perfect climate foresight • Applies design-life climate change projections to construction design • **Incurs up-front costs** to adapt roads, avoiding life-cycle degradation • **Range of GCMs**: 25%, 50% (median), 75% and 100% (most extreme) climate scenarios • Certain types of infrastructure can be chosen to be adapted or not adapted ("**partial adapt analysis**")	• "**Business as usual**" • Assumes no adaptations are put into place – current design standards are used to build new roads and rehabilitate existing roads • **Costs incurred from increased maintenance** necessary to retain design life of original structure as degradations are incurred from increased climate stress

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Adapt vs. No Adapt Policy Approach

Some examples of the costs incurred:

ROAD TYPE	ADAPT	NO ADAPT
Paved	• Upgrade asphalt binder type (temp. increase) • Increase drainage capacity (culvert size)	• Increased rutting and cracking • Increased washout and drainage infrastructure damages
Gravel	• Increase sub-base • Increase drainage capacity • Increase grading	• Increased spot and annual maintenance required from damages • Increased washout/loss of use
Unpaved	• Upgrade to gravel road	• Increased annual and spot maintenance required • Increased washout • Loss of connectivity/usage

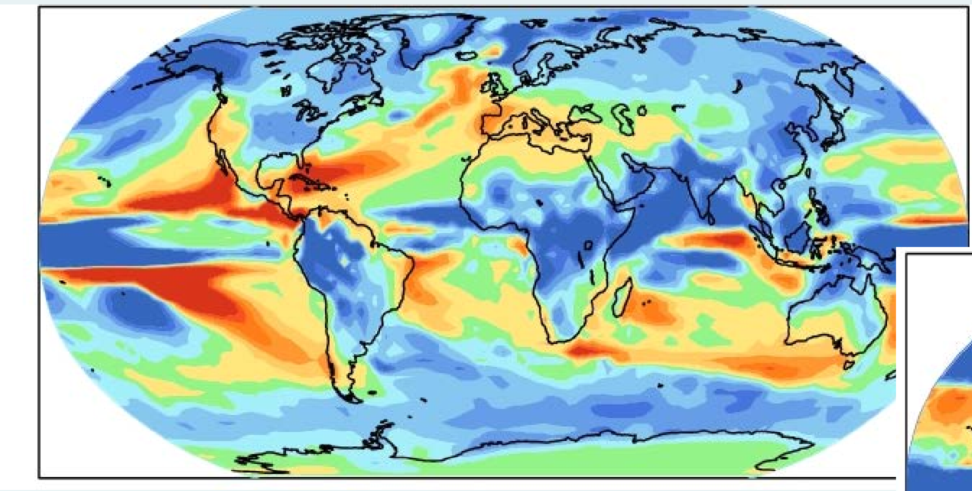
IPSS Components & Analysis

IPSS analyzes climate impact in six areas for a holistic approach

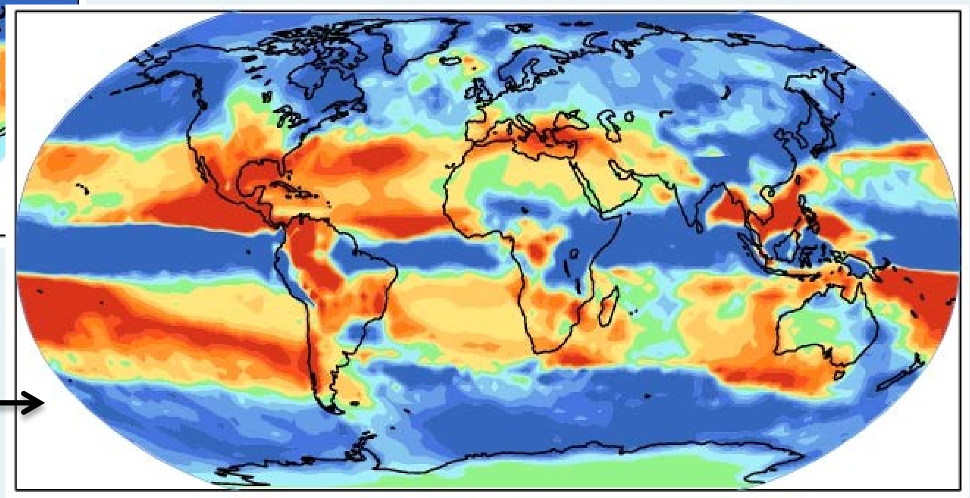
Areas of Analysis	Key Variables
Climate	Precipitation, temperature
Flooding	Runoff, intensity, infrastructure density
Environment	Carbon emissions, traffic, freight
Transport	Distance, road type, traffic, freight
Finance	Interest rate, duration of loan, finance type
Social	Poverty rate, population density, (optional) labour- intensive construction, road density, road type

Incorporated Data Sources

Climate data comes from internationally approved climate scenarios (Global Circulation Models [GCMs]). Can use Hybrid Frequency Distribution Models (HFDs).



Precipitation - 2100
NCAR



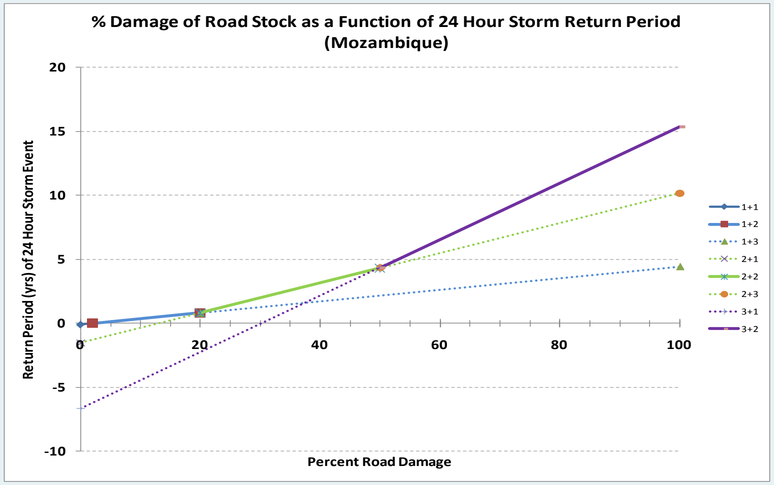
Precipitation - 2100
MIROC

Data & Methodology

Stressor-Response Functions:

- Flooding, Precipitation, Temperature
- Analyze existing climate vs. projected future climate
- Existing weather studies are used to estimate damages from climate changes

Flooding Step-Wise Damage Function



Climate Impact Costs for New Construction

Cp = (NTHRESH * SCI) * BPG

Where C_P = change in construction costs for paved and gravel roads associated with a climate stressor,

N_{THRESH} = Number of precipitation or temperature thresholds exceeded

SCI = Stressor Cost Increase per threshold increase, and

B_{PG} = base construction costs for paved or gravel roads.

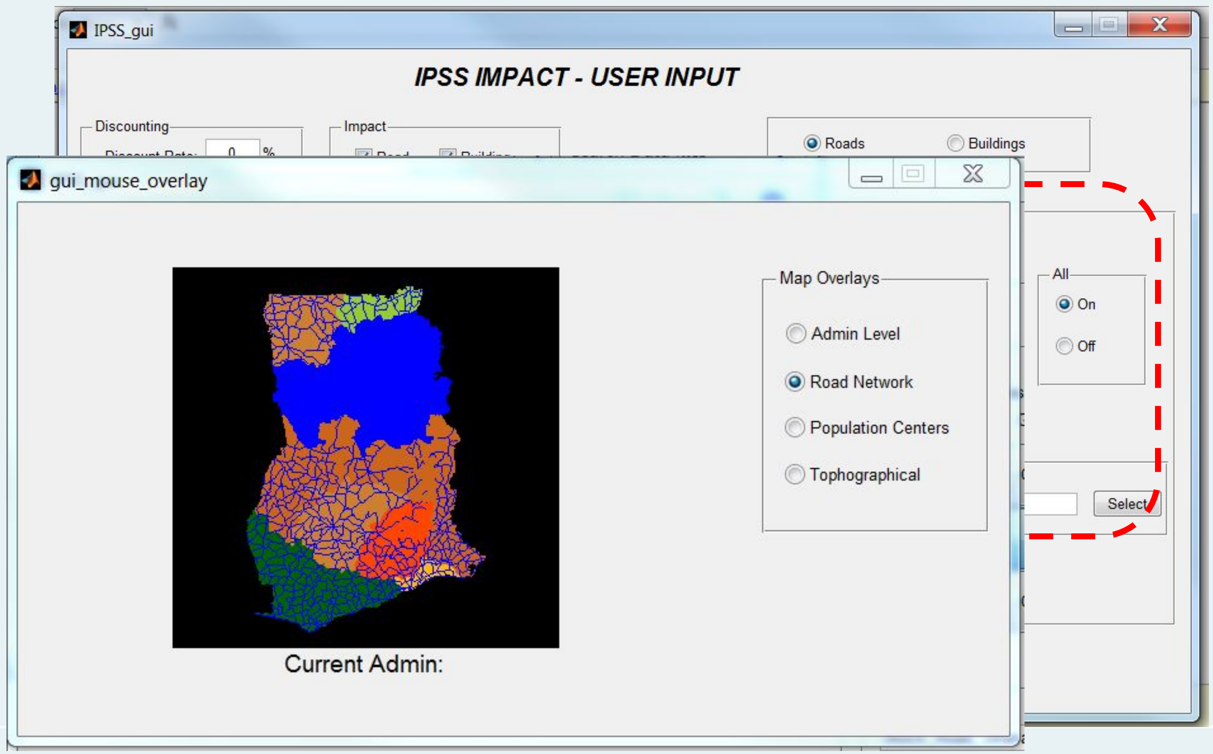
Overview of User Experience:

Inputs, Outputs & Application

User Input Data

- Road Stock Inventory Data
  - Existing inventory and/or planned future inventory
    - Road class (primary, secondary, tertiary)
    - Road type (paved, gravel, unpaved)
    - Region (administrative area)

- Additional components require:
  - Population data and poverty rates
  - Traffic projections
  - Building inventory



Measurements of Impact (Output)

- **Total Cost**: The estimated costs of climate change impacts with an optional (user-defined) discount rate applied.

- **Opportunity Cost:** Percentage of new, secondary paved road inventory that could be built if money was not diverted to climate change (if climate change did not happen) through 2100, relative to country's existing roads

- **Maintenance Savings**: The amount incurred in savings on maintenance for upgraded roads.

- **Adaptive Advantage:** The benefit (in savings, if it exists) between the Adapt and No Adapt policies.

Output

Excel workbook: Summary Costs for selected roads, time period

Road Costs (USD Million) - Mean	Paved		Gravel		Unpaved		Total	
	Adapt	No Adapt	Adapt	No Adapt	Adapt	No Adapt	Adapt	No Adapt
Flooding								
Climate								
Total (Combined)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Selected Road Costs - Adapt (USD Million)		Road Type: Paved	Gravel	Unpaved
2030				
Avg Annual Cost (USD Millions)	25th			
	50th			
	75th			
	100th			
2050				
Avg Annual Cost (USD Millions)	25th			
	50th			
	75th			
	100th			
2090				
Avg Annual Cost (USD Millions)	25th			
	50th			
	75th			
	100th			

Selected Road Costs - No Adapt (USD Million)		Road Type: Paved	Gravel	Unpaved
2030				
Avg Annual Cost (USD Millions)	25th			
	50th			
	75th			
	100th			
2050				
Avg Annual Cost (USD Millions)	25th			
	50th			
	75th			
	100th			
2090				
Avg Annual Cost (USD Millions)	25th			
	50th			
	75th			
	100th			

Output

Excel workbook: Detailed Costs for road type by administrative unit

Selected Road Costs - Adapt (USD Million)		Paved Primary			Paved Secondary			Paved Tertiary			Gravel Primary		
		Climate	Flood	Total	Climate	Flood	Total	Climate	Flood	Total	Climate	Flood	Total
2030													
Avg Annual Cost (USD Millions)	25th												
	50th												
	75th												
	100th												
2050													
Avg Annual Cost (USD Millions)	25th												
	50th												
	75th												
	100th												
2090													
Avg Annual Cost (USD Millions)	25th												
	50th												
	75th												
	100th												

Road Type

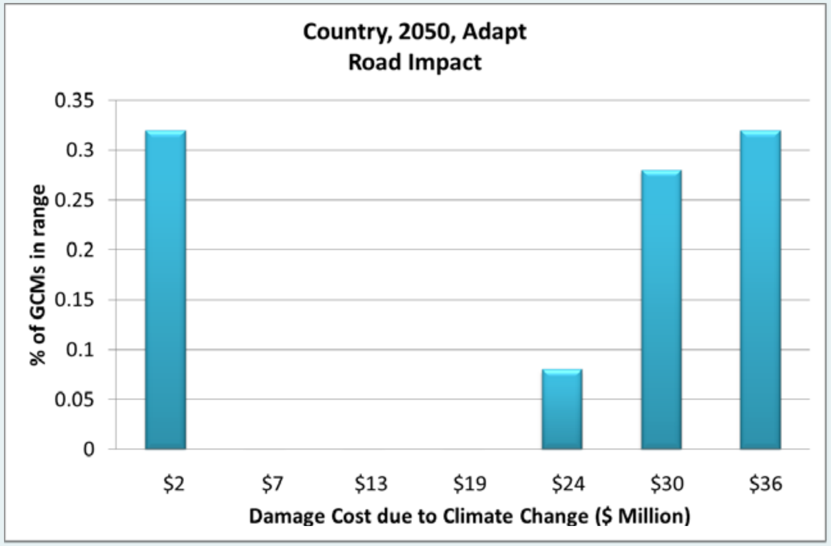
Selected Road Costs - No Adapt (USD Million)		Paved Primary			Paved Secc	
		Climate	Flood	Total	Climate	Flooc
2030						
Avg Annual Cost (USD Millions)	25th					
	50th					
	75th					
	100th					
2050						
Avg Annual Cost (USD Millions)	25th					
	50th					
	75th					
	100th					

	A	B	C
1		Roads - Adapt ($USD Million	Roads - Adapt KM Lost Rc
2	Abura-Asebu-Kwamankese	0	0.03
3	Accra	0.05	0.36
4	Adaklu Anyigbe	0.03	0.22
5	Adansi North	0	0
6	Adansi South	0.01	0.09
7	Afigya Sekyere	0	0
8	Afram Plains	0.04	0.29
9	Agona	0.01	0.04
10	Ahafo Ano North	0.96	6.41
11	Ahafo Ano South	0.36	2.41
12	Ahanta West	0.02	0.13
13	Ajumako-Enyan-Esiam	0	0.03
14	Akatsi	0.06	0.42
15	Akwapim North	0.14	0.94
16	Akwapim South	0	0
17	Amansie Central	0.01	0.05
18	Amansie East	0.02	0.17
19	Amansie West	0	0

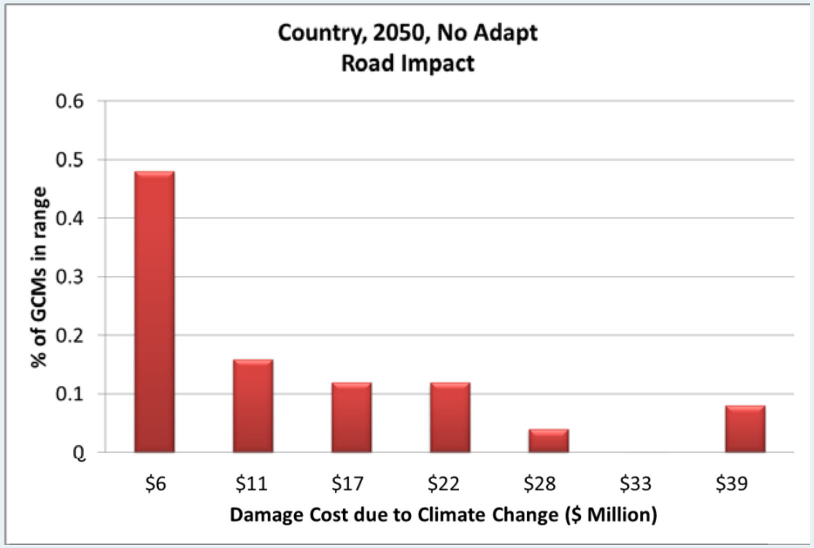
Output

Graphical display of uncertainty from GCM and/or cost variations from Adaptation Policy

Adapt



No Adapt



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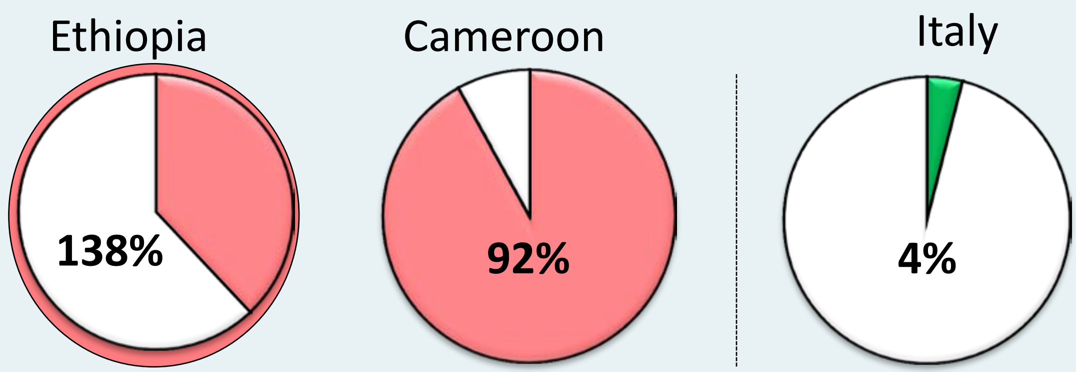
Application

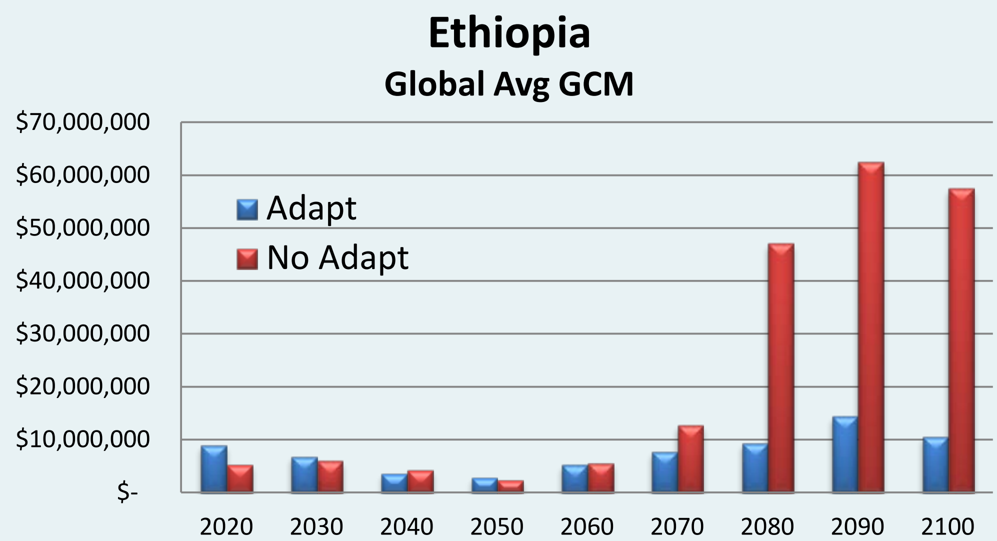
10-Country Study

- Six GCMs chosen to compare the absolute and relative impact of climate change on road infrastructure in ten countries

- **Developing Vs. Developed**: Showed significant differences between countries
  - %GDP
  - Opportunity Cost

Selected Study Results



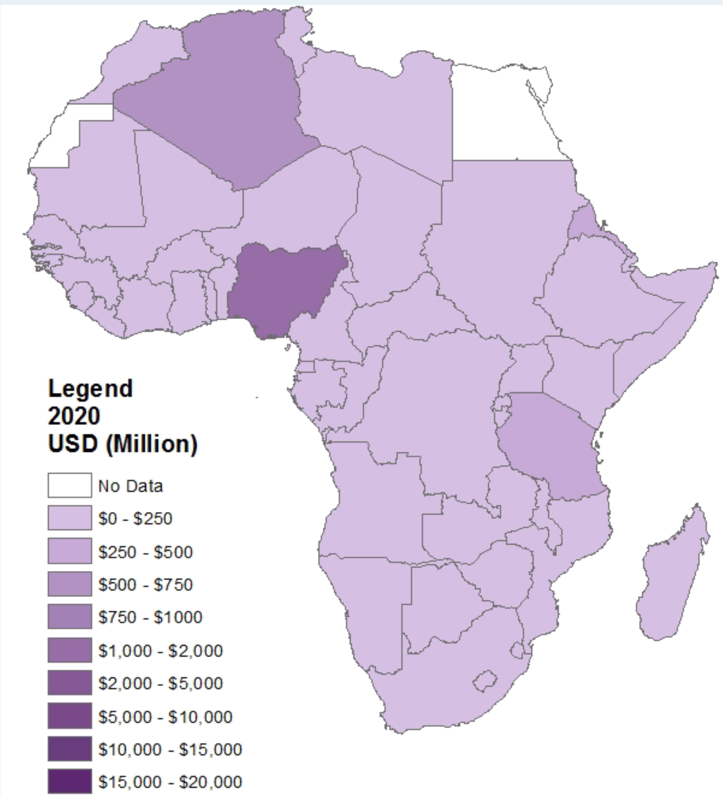


Application

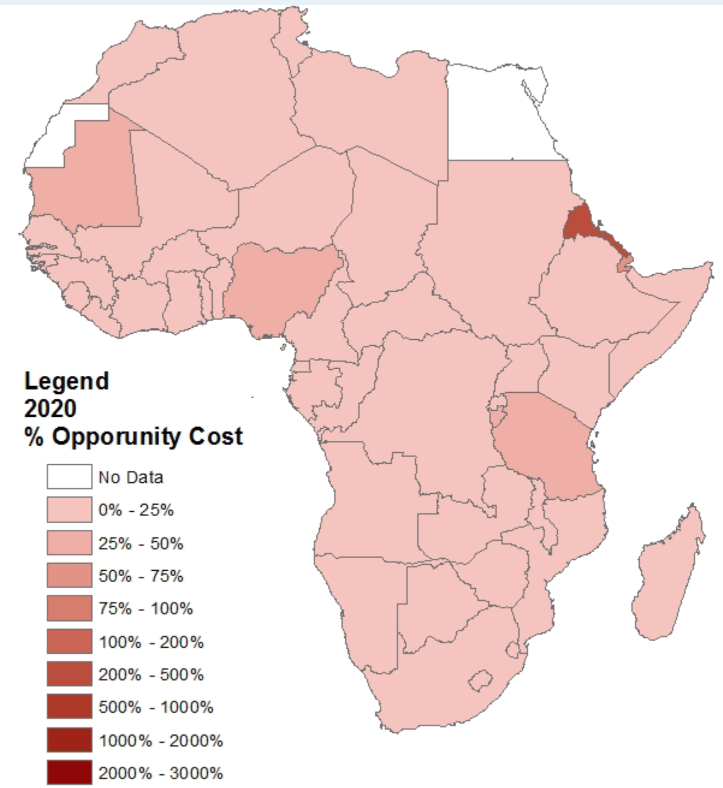
Pan-African Analysis

"Adaptation Advantage to Climate Change Impacts on Road Infrastructure in Africa Through 2100"(Chinowsky, et al, 2011) *Climatic Change*

Total Cost ($USD)



Opportunity Cost (%)



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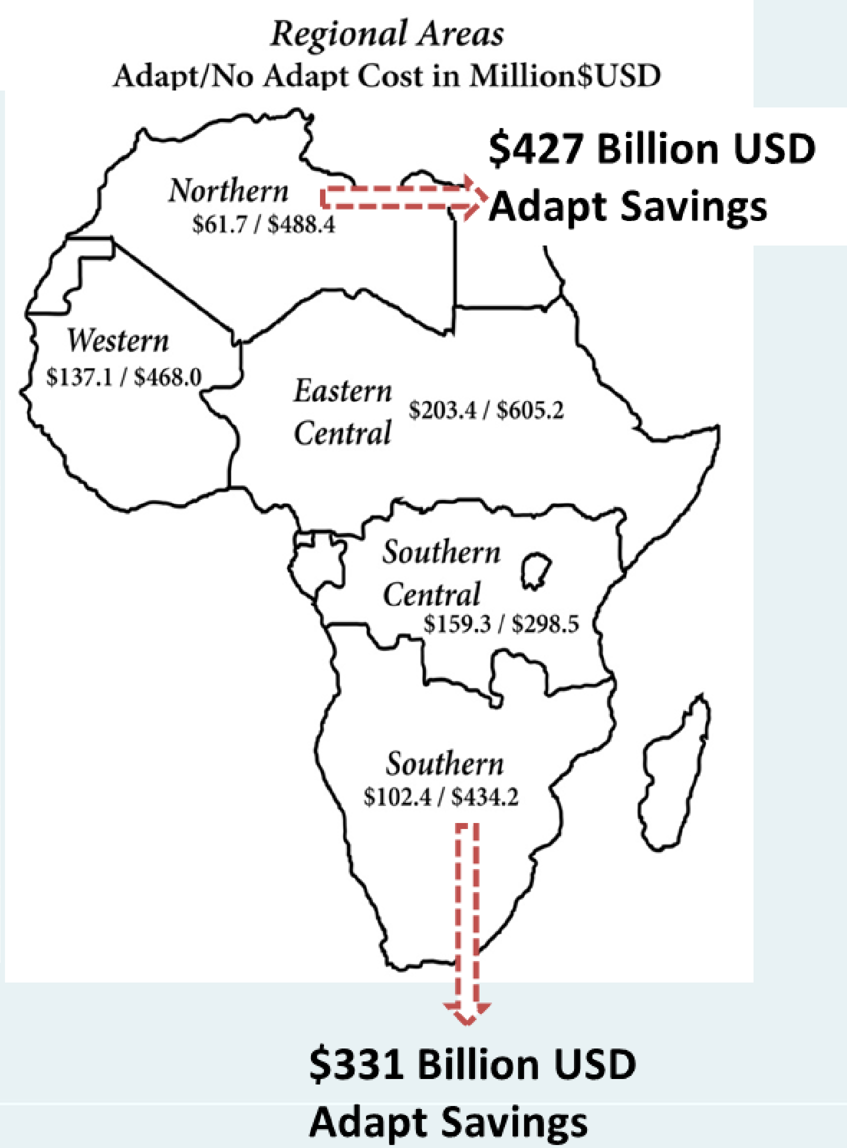
Application

Pan-African Analysis

"Adaptation Advantage to Climate Change Impacts on Road Infrastructure in Africa Through 2100" (*Chinowsky, et al, 2011*) Climatic Change

Country	Planning Approach	Total Cost (Millions USD)	Opportunity Cost	Kilometres Lost
Malawi	*Adapt*	156	38%	2,660
	No Adapt	190	71%	4,960
Mozambique	*Adapt*	355	101%	5,760
	No Adapt	186	83%	4,720
Zambia	*Adapt*	739	60%	12,100
	No Adapt	547	66%	13,320



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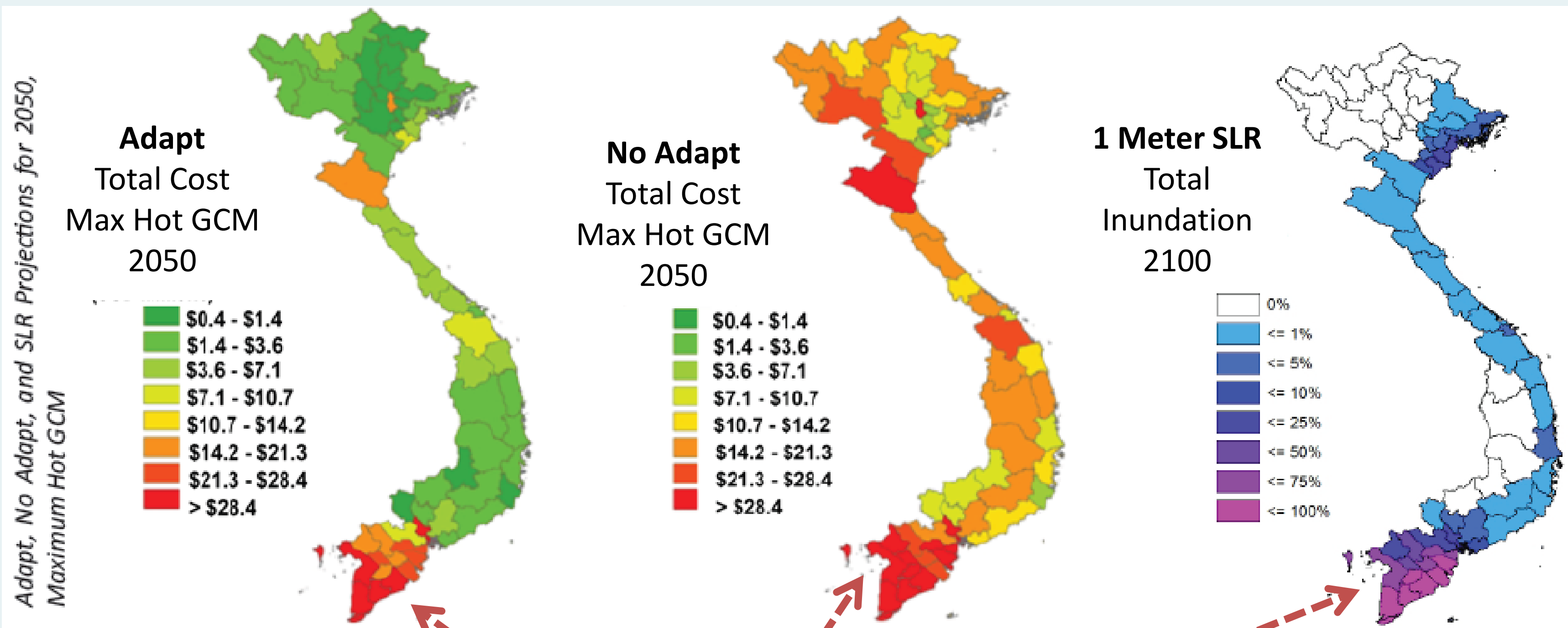
Application

Avg. Range of **Total Cost** estimates:
USD$3.6 – $7.2 billion /annum
(Mean GCM: ***Opp. Cost of 92%***)

Vietnam: Road Infrastructure

- Included sea level rise

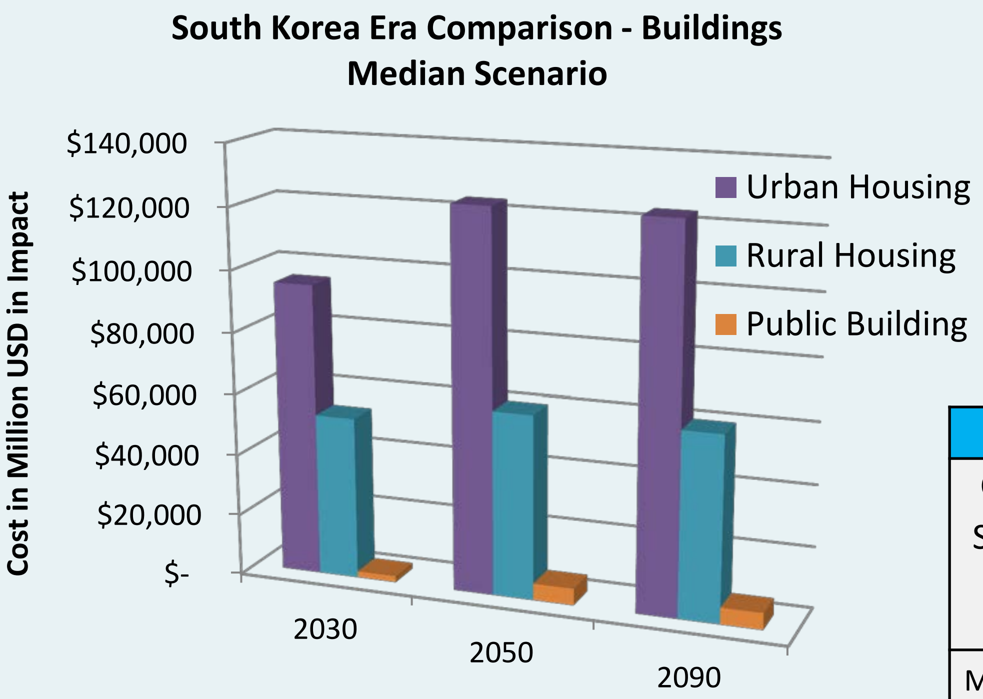


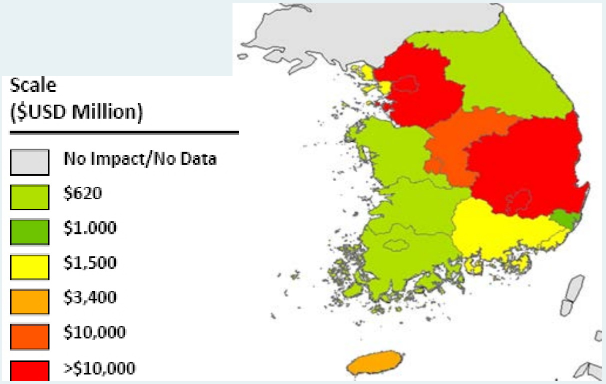
Complete inundation of some coastal provinces

Next Steps

Expanding to include other types of infrastructure

Preliminary study on 4 Asian Countries - Results from *South Korea*

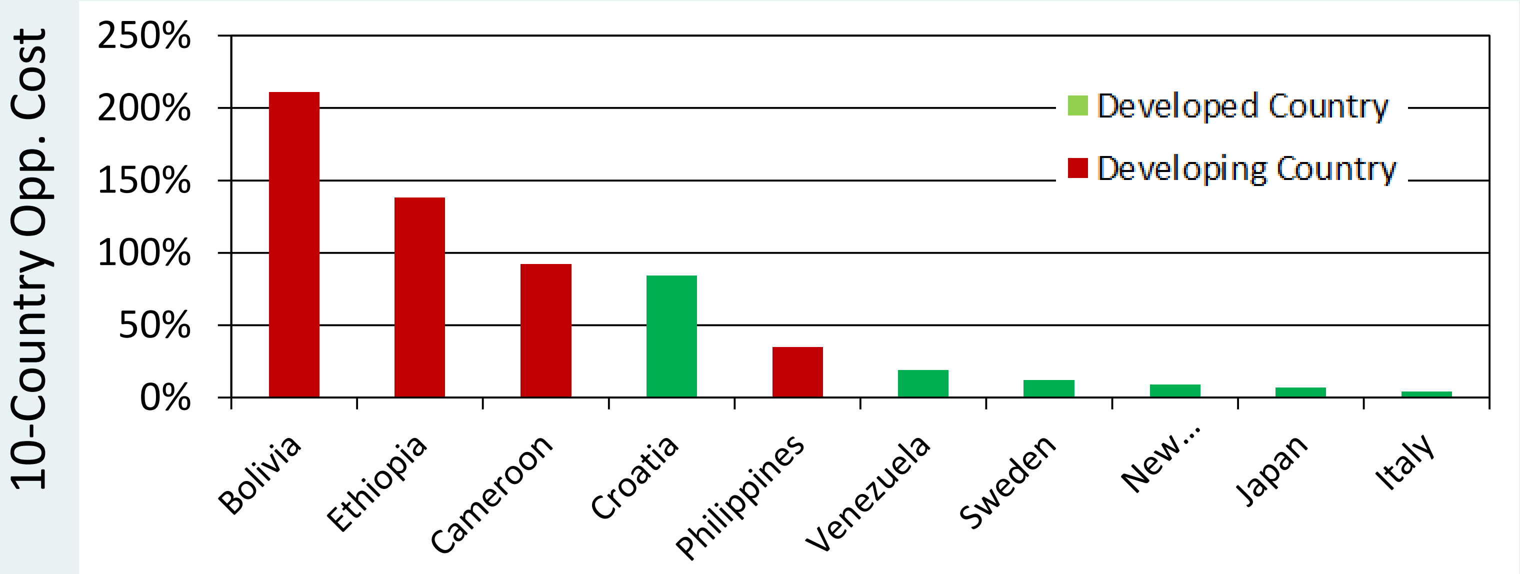




SOUTH KOREA - 2050 Era, Average Annual Cost				
Climate Scenario	Adapt	No Adapt	Opp. Cost (Adapt)	Opp. Cost (NA)
	(USD$ Million)	(USD$ Million)	%	%
Max	$ 210	$ 572	2%	5%
Median	$ 159	$ 195	1%	2%
Minimum	$ 128	$ 74	1%	1%

Summary

- Capacity building is critical in extending considerations for road investments and adaptation
- Adaptation and mitigation can drastically reduce impacts
- Opportunity costs must be considered when evaluating climate change impacts



Thank you!

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