The Heterogeneous Effects of Transportation Infrastructure: Evidence from Sub-Sahara Africa

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WORK IN PROGRESS

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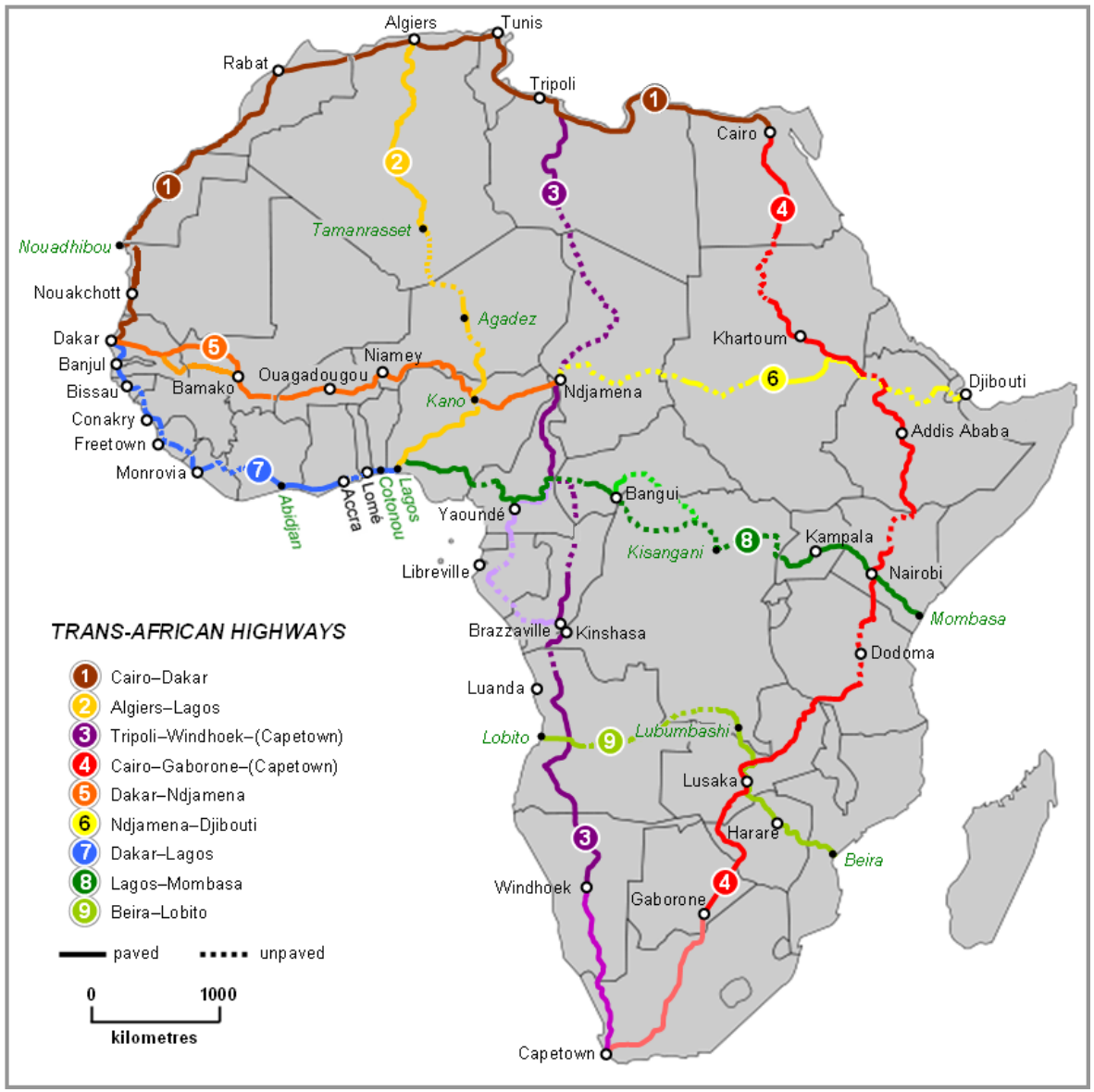
Research Questions

- **How has intercity road upgrading affected local economic development in Sub-Saharan Africa?**
- **What are the implications for current/future road-building efforts?**
  - About 1/5 of World Bank lending on transport, 13% on roads.
  - Large fraction of network still unpaved
  - Trans-African Highway network as coordinating mechanism: 55,000 km of planned highways (vs. 1,000 km of highways in c. 2012).
    - Abidjan-Lagos Motorway: $8 billion
    - LAPSSET Project in Kenya-Ethiopia-South Sudan: $22 billion
    - Gauteng-Maputo Development Corridor: $5 billion
- **What are the implications for African urbanization?**
  - Expected increase 30% in 2010 to 50% in 2030: which cities?

Effects of Possible Future Highway Networks?



What We Do

- Build a **new panel data set** on road surface, city population and market access for 39 Sub-Saharan African countries 1960-2010.

- Estimate the average effects of **market access** changes (as induced by road surface changes) on city growth.
  - market access is a measure summarizing a city's access to all other cities.
  - a doubling of market access induces a 5–18% increase in city population
  - effect spread up to 30 years after road upgrading

- Also investigate the **heterogeneous effects** of road changes:

Related work

- Highway infrastructure impacts in China, USA, India, Brazil,
- Rail infrastructure impacts in China, USA, India, Ghana, Kenya
- Micro road surface/quality impacts in Sierra Leone (agricultural prices), Indonesia (manufacturing employment), Mexico (household wealth)
- Transport and trade costs in Africa - variation from other sources:
  - Fuel prices
  - inferred from price changes of very specific goods
- Our contributions:
  - Scale: 39 countries, 6 time slices over 50 years
  - Timing and heterogeneous effects.
  - Not just building highways: paving and improving (gravelling)

Outline

- Data
- Estimation
- Results
- Conclusion

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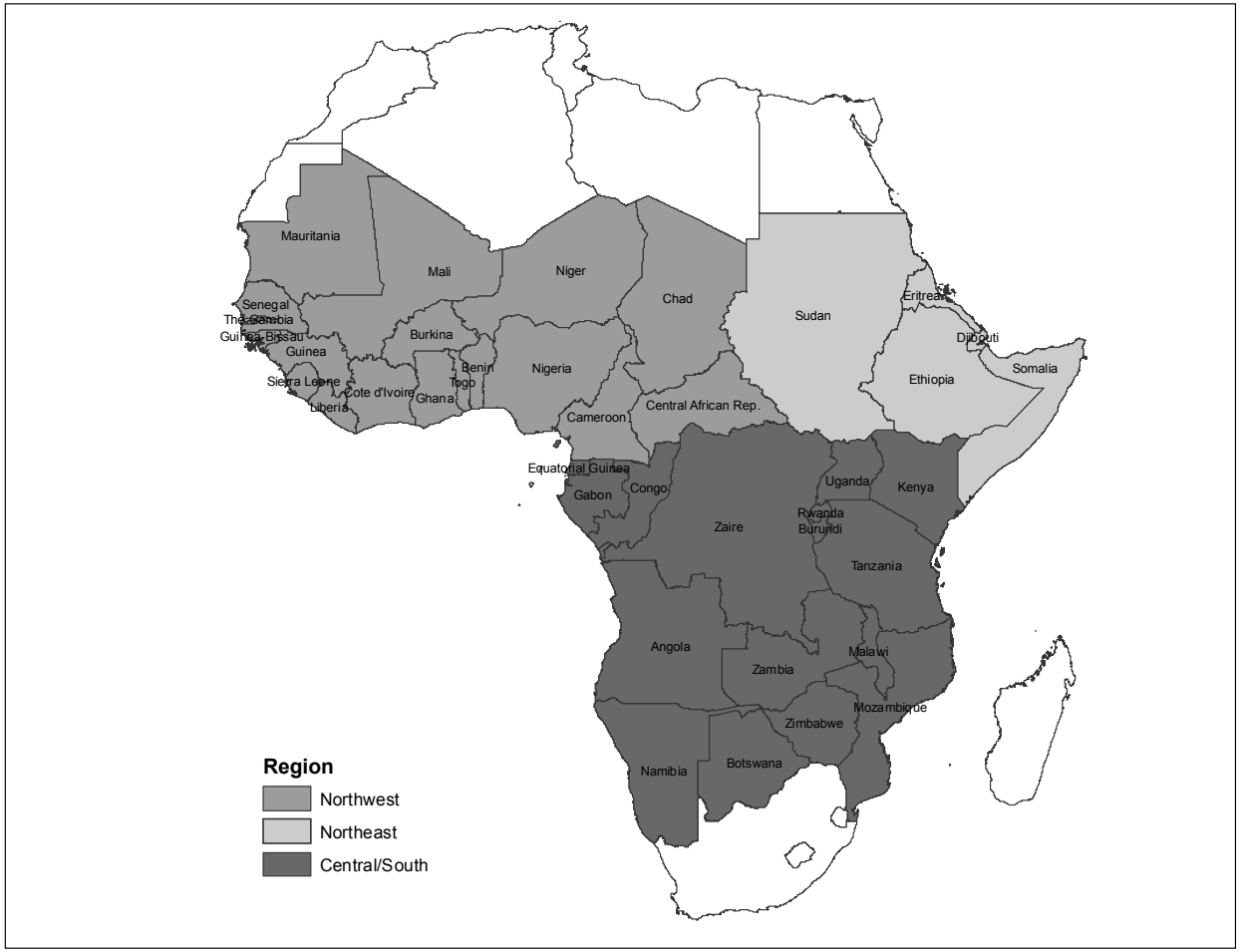
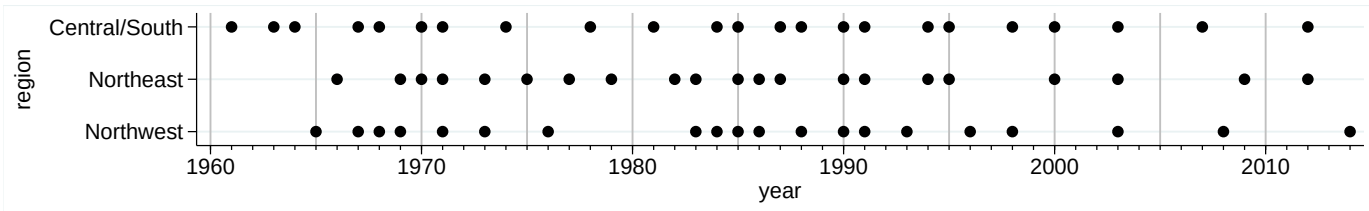
Data: Roads

GIS database of roads:

- *Michelin* paper road maps for 39 Sub-Saharan African countries from the early 1960s to date. Sources:
  - Government maps
  - Feedback from customers (large network of tire distributors and correspondents)
- Map $\approx$ every 3 years, so 833 country-years
- Surface of each road: *Highway*, *Paved*, *Improved* and *Dirt* (vs. Primary, secondary, tertiary)
- No city streets

Michelin Road Map Countries and Years



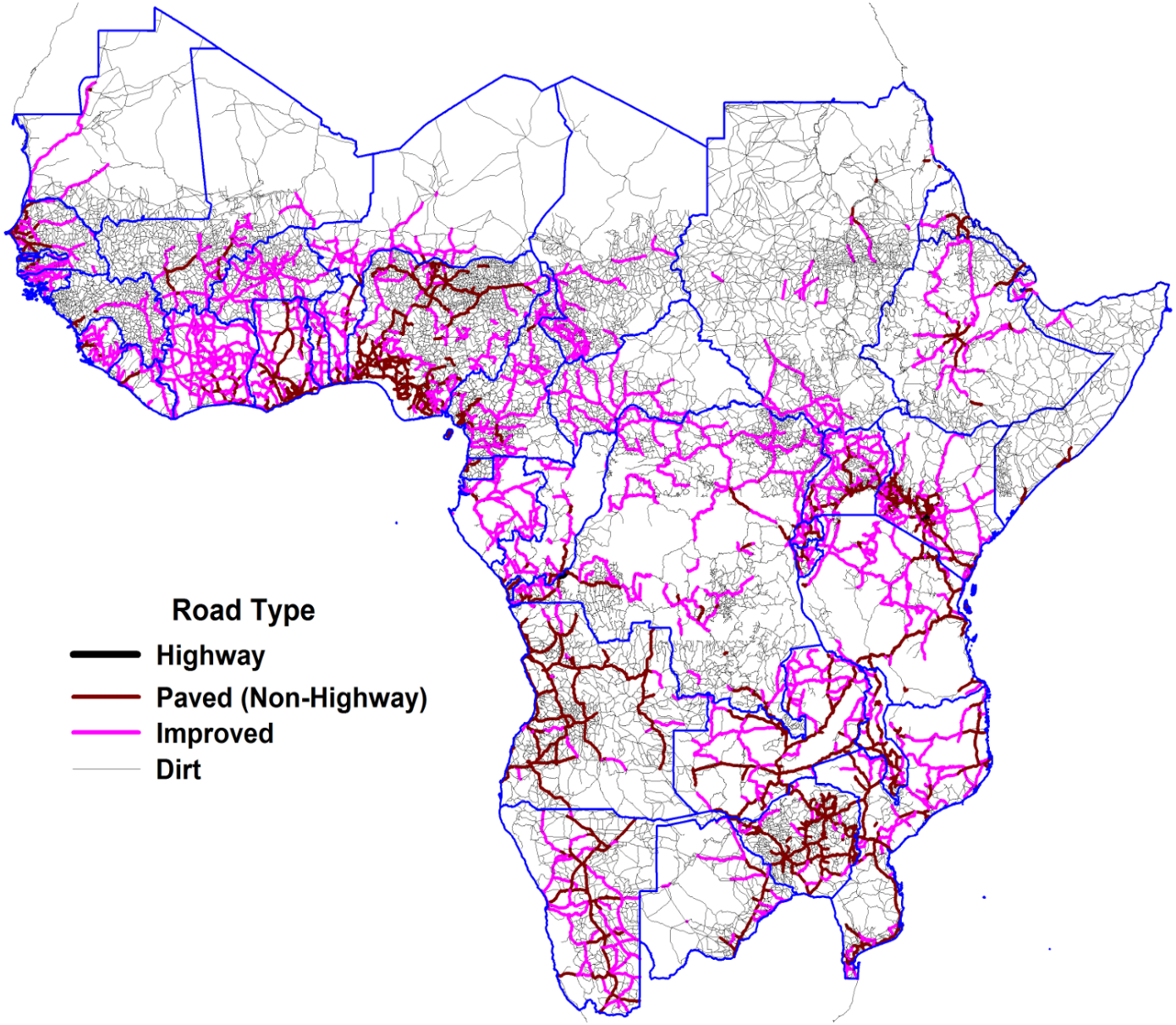


Michelin Road Map for Liberia in 1965

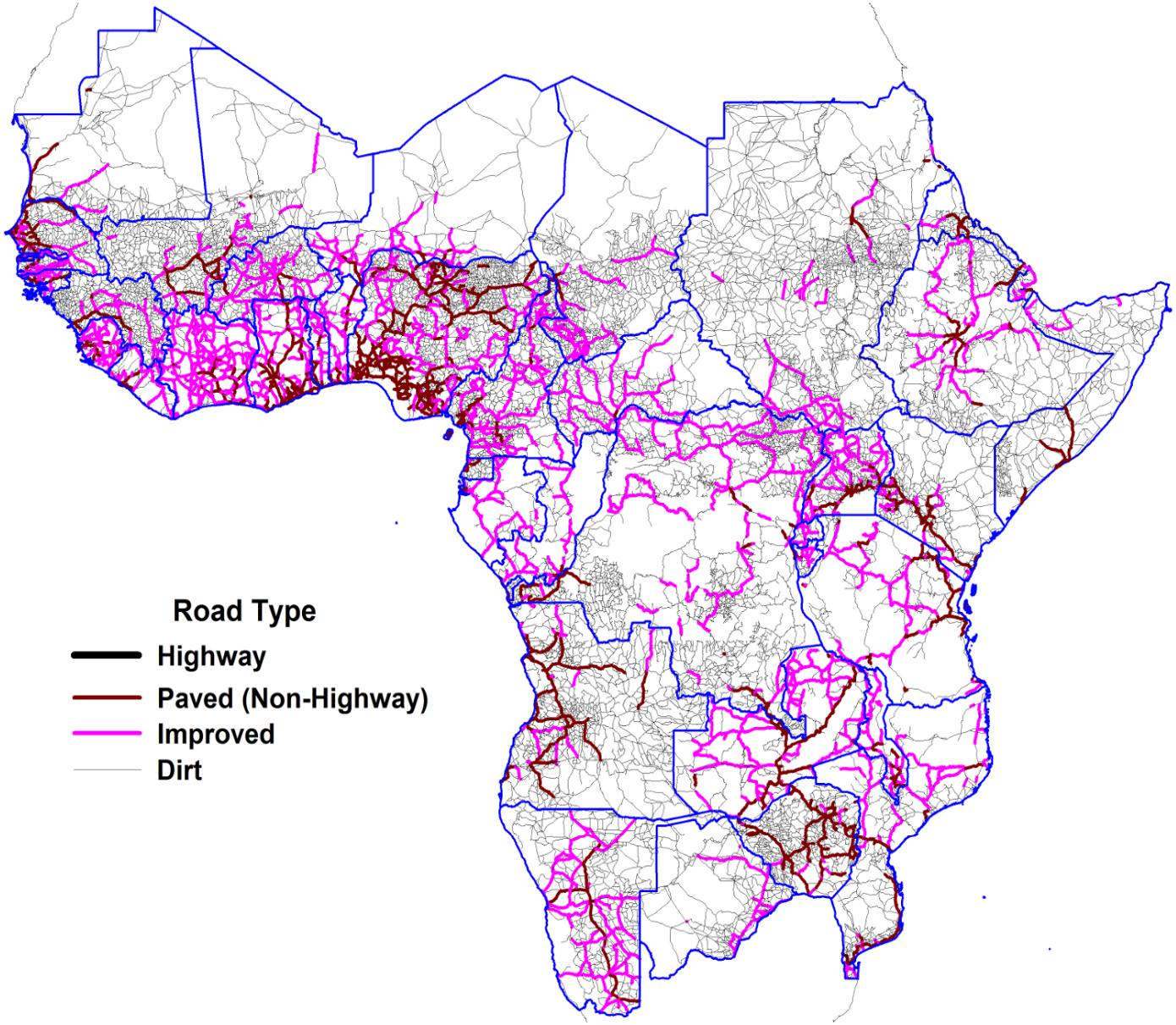
Surfaces aggregated into 4 categories: *Highway*, *Paved*, *Improved* and *Dirt*

Four Road Surface Categories

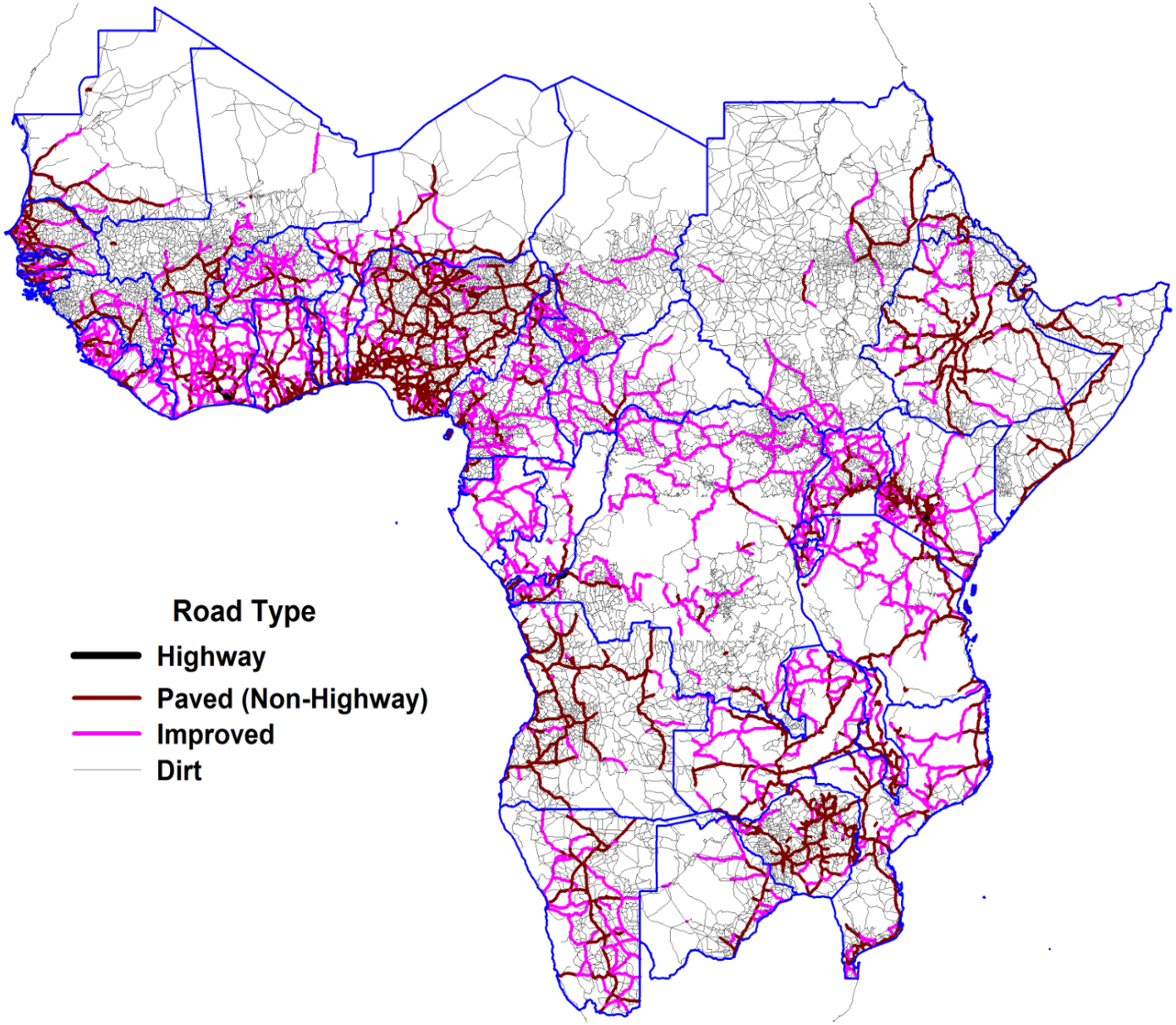
Roads in 1960



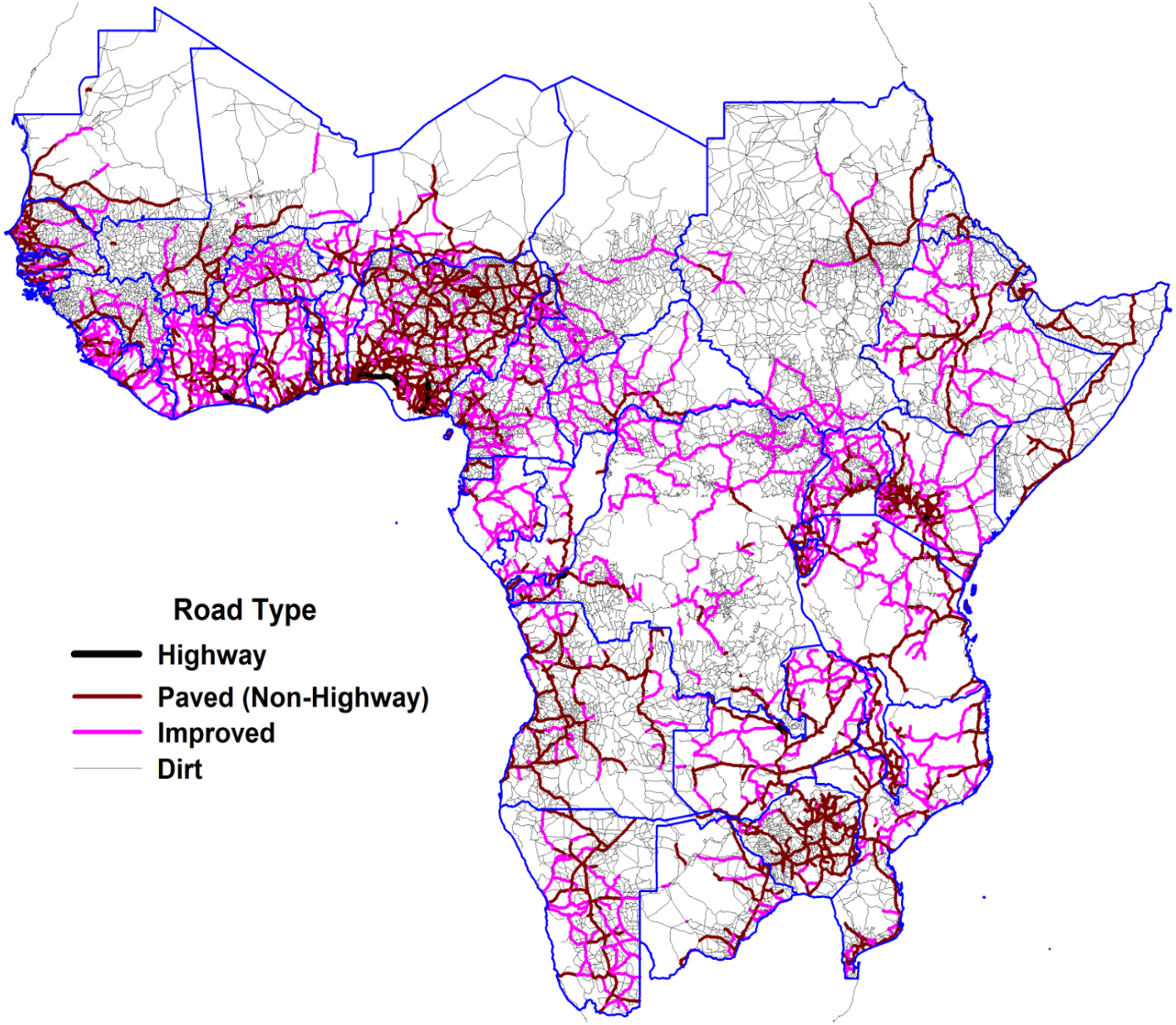
Roads in 1970



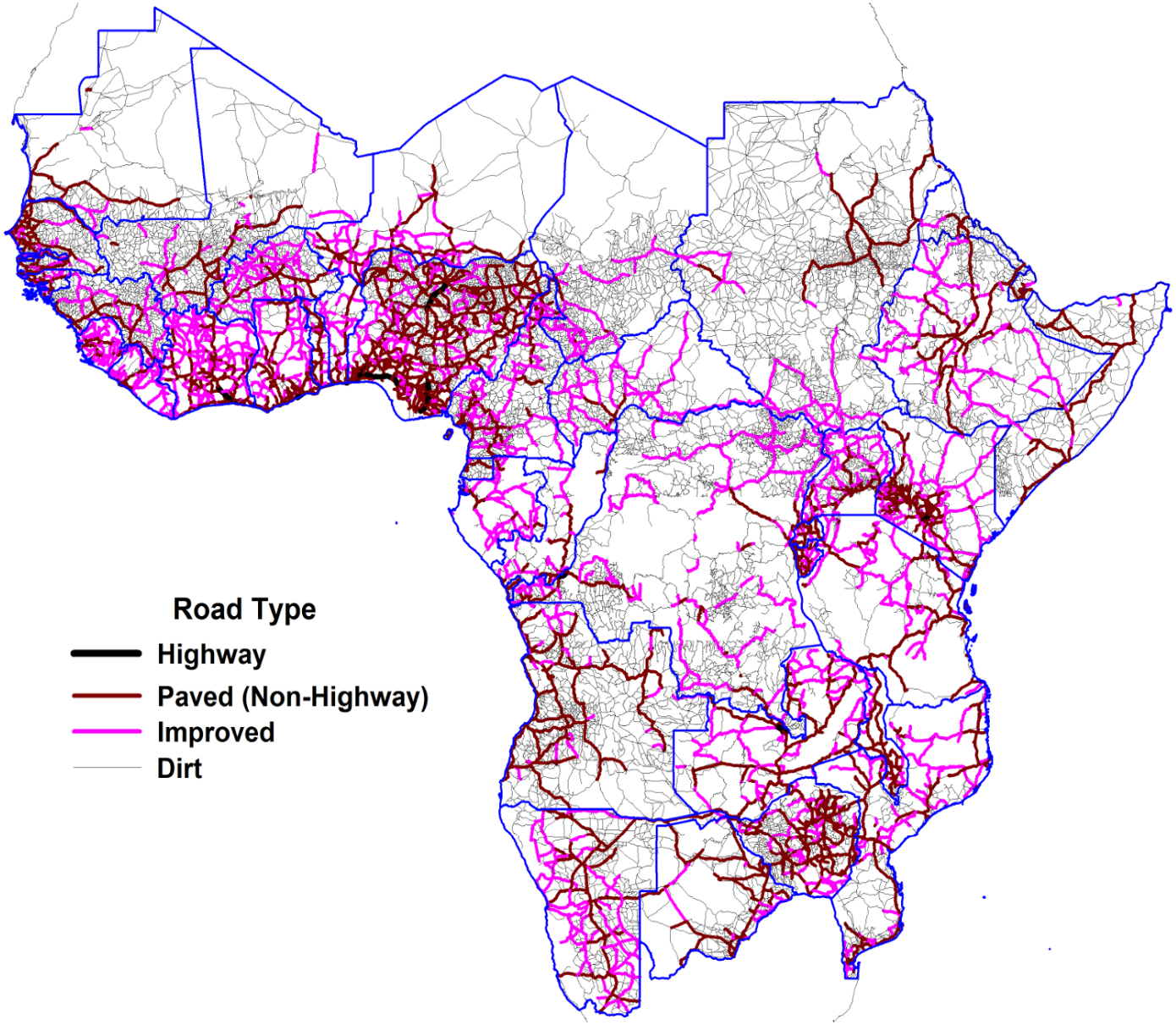
Roads in 1980



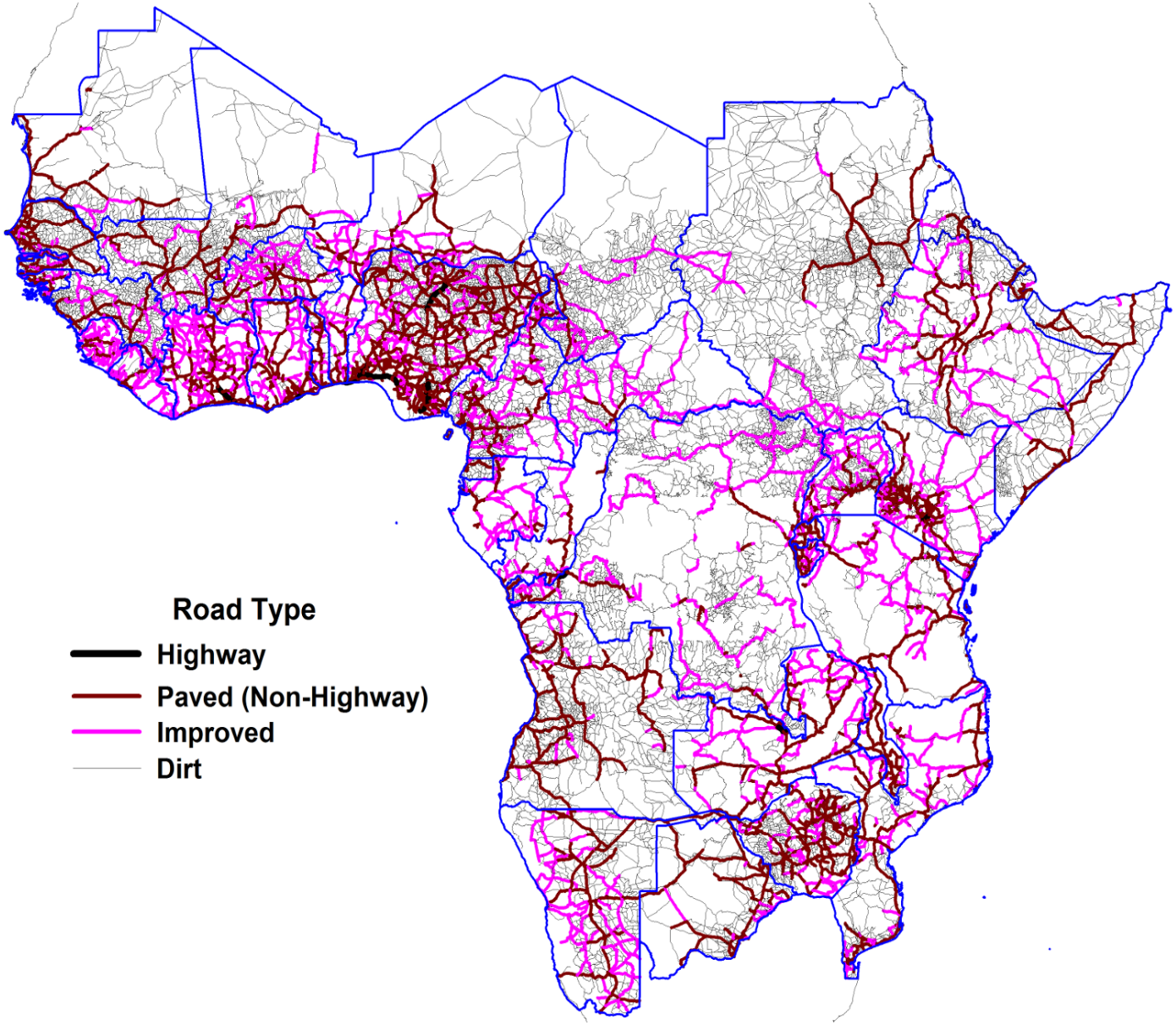
Roads in 1990



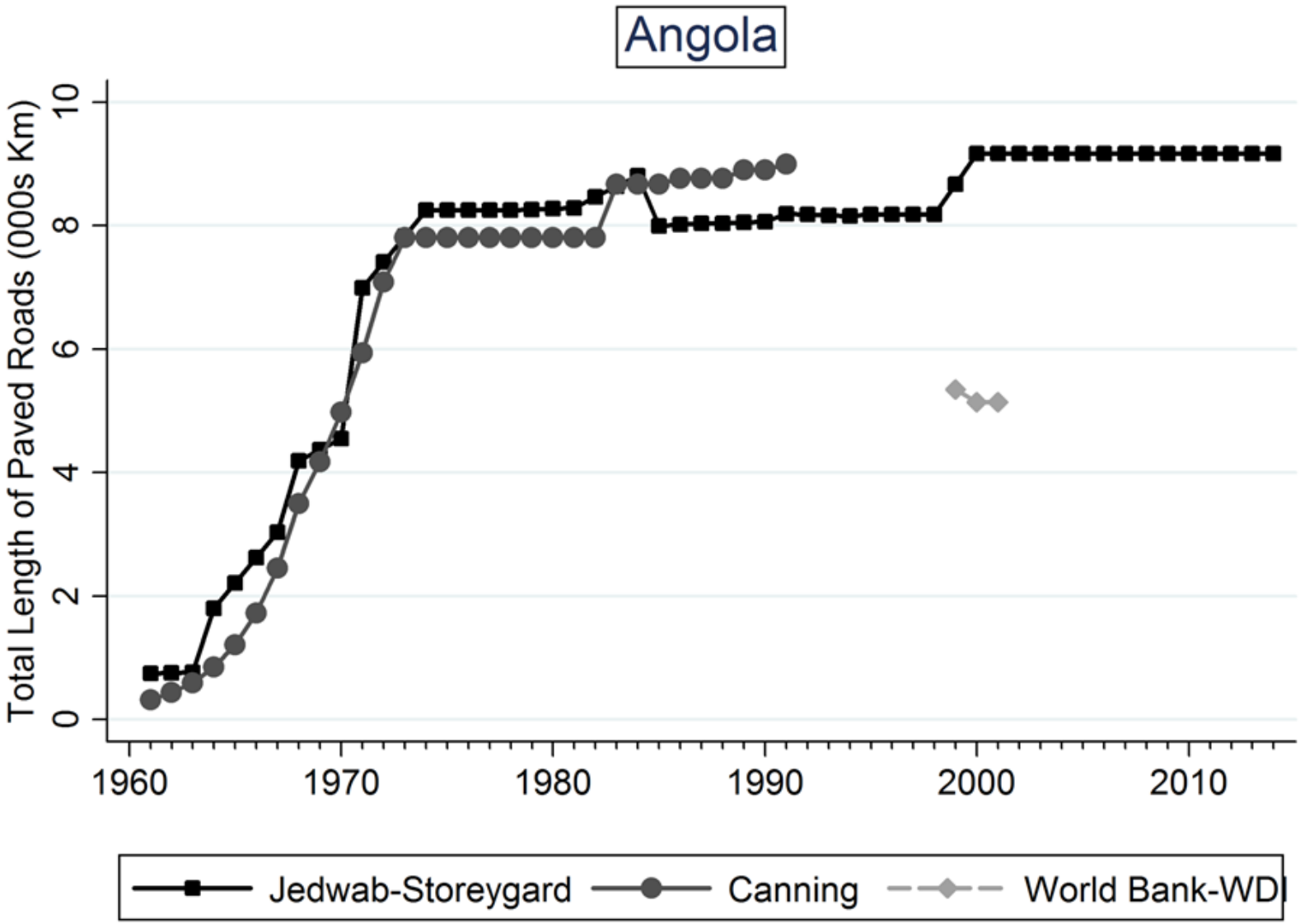
Roads in 2000



Roads in 2010



Road Length: Michelin vs. Canning (2008) vs. World Bank



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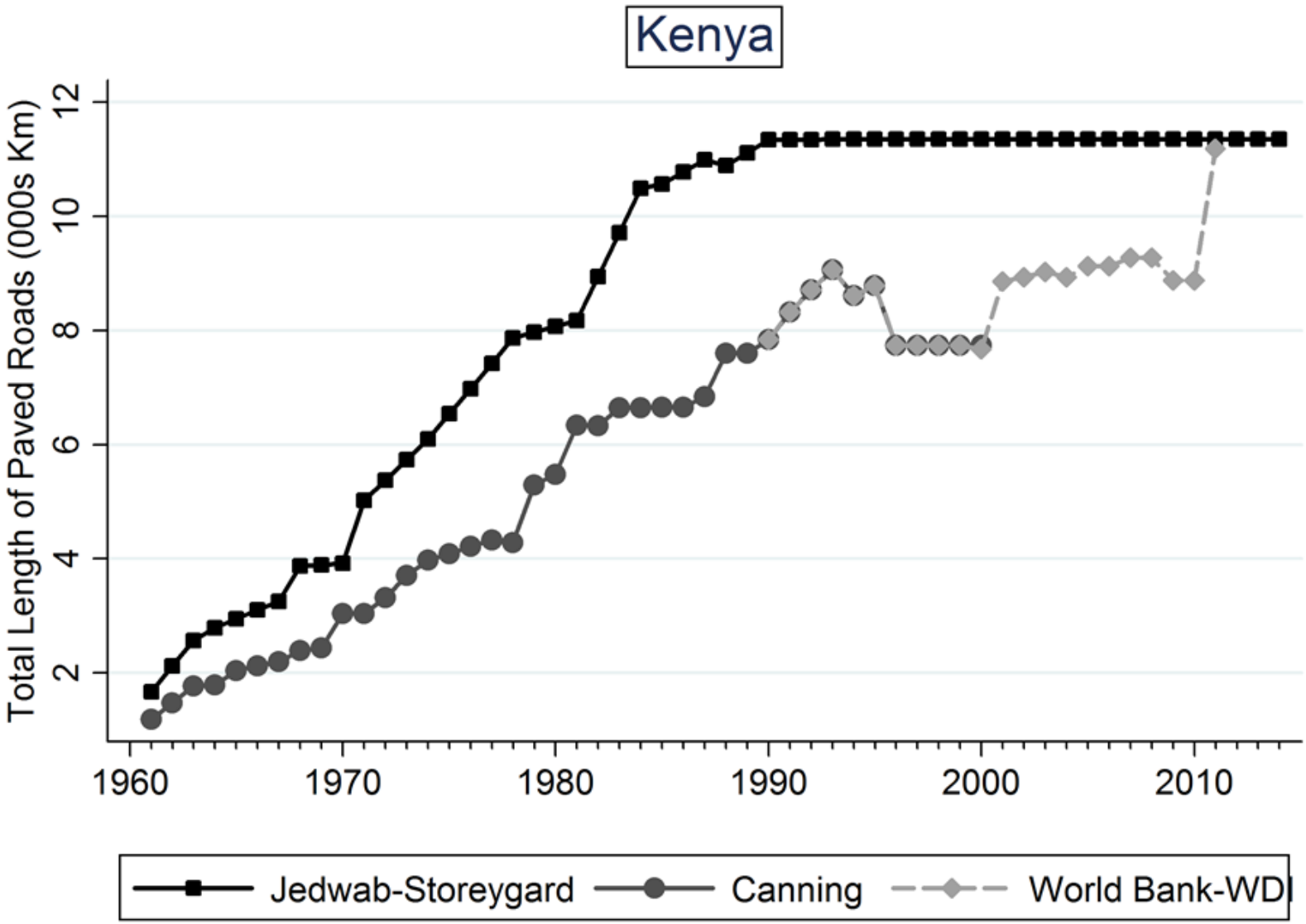
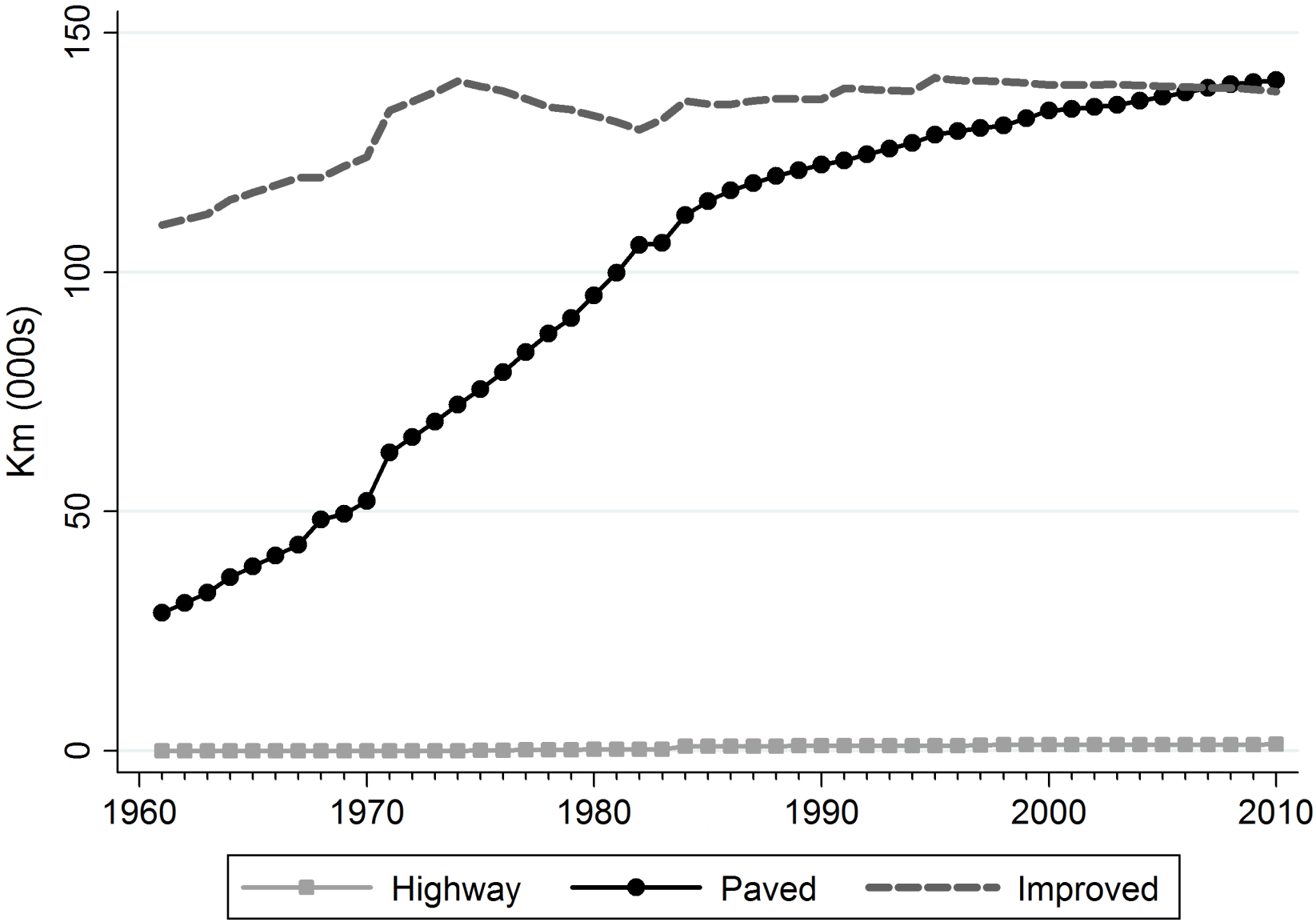
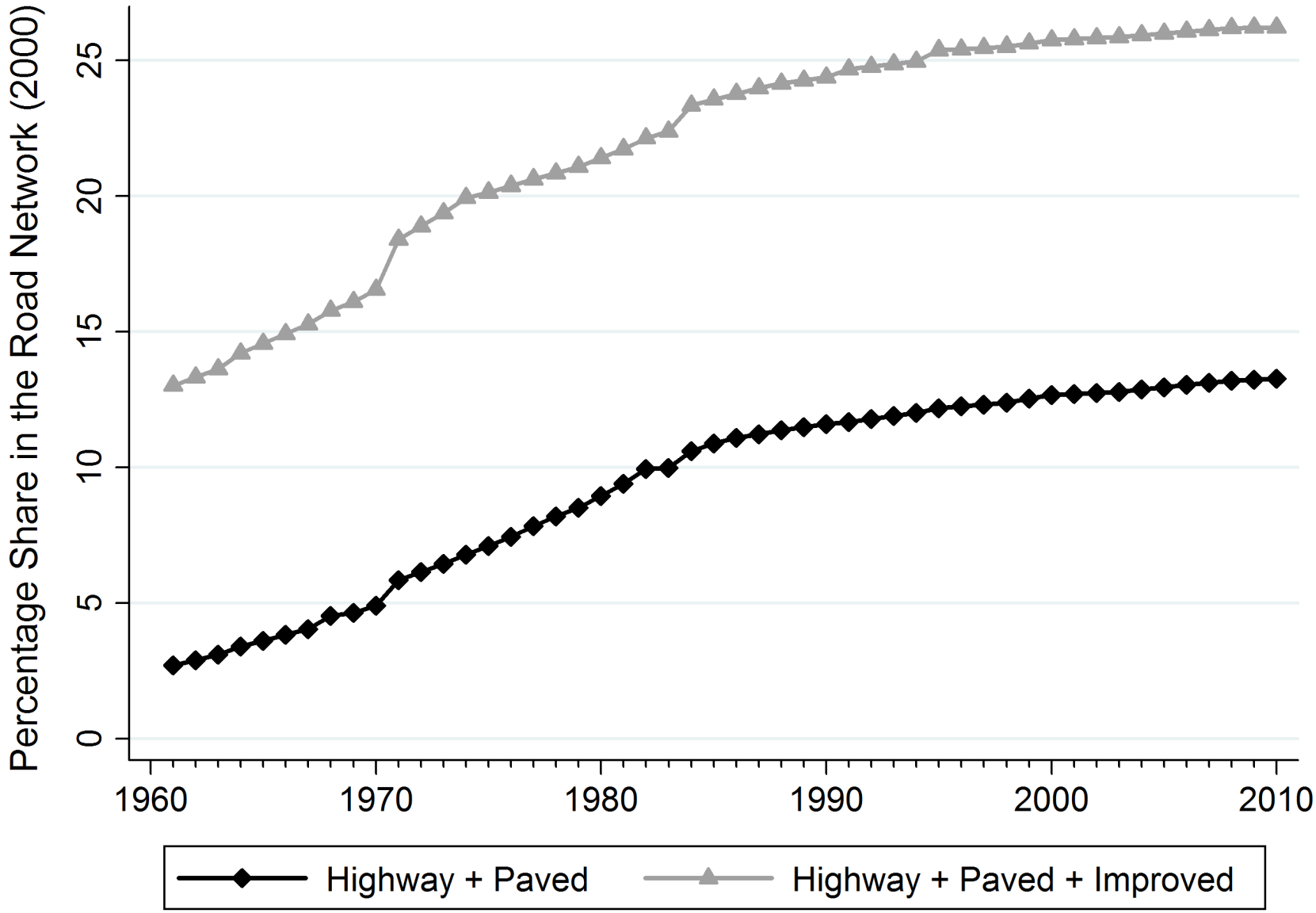


Road Length in Sub-Saharan Africa (39 Countries)



Percentage Share in the Road Network (39 Countries)

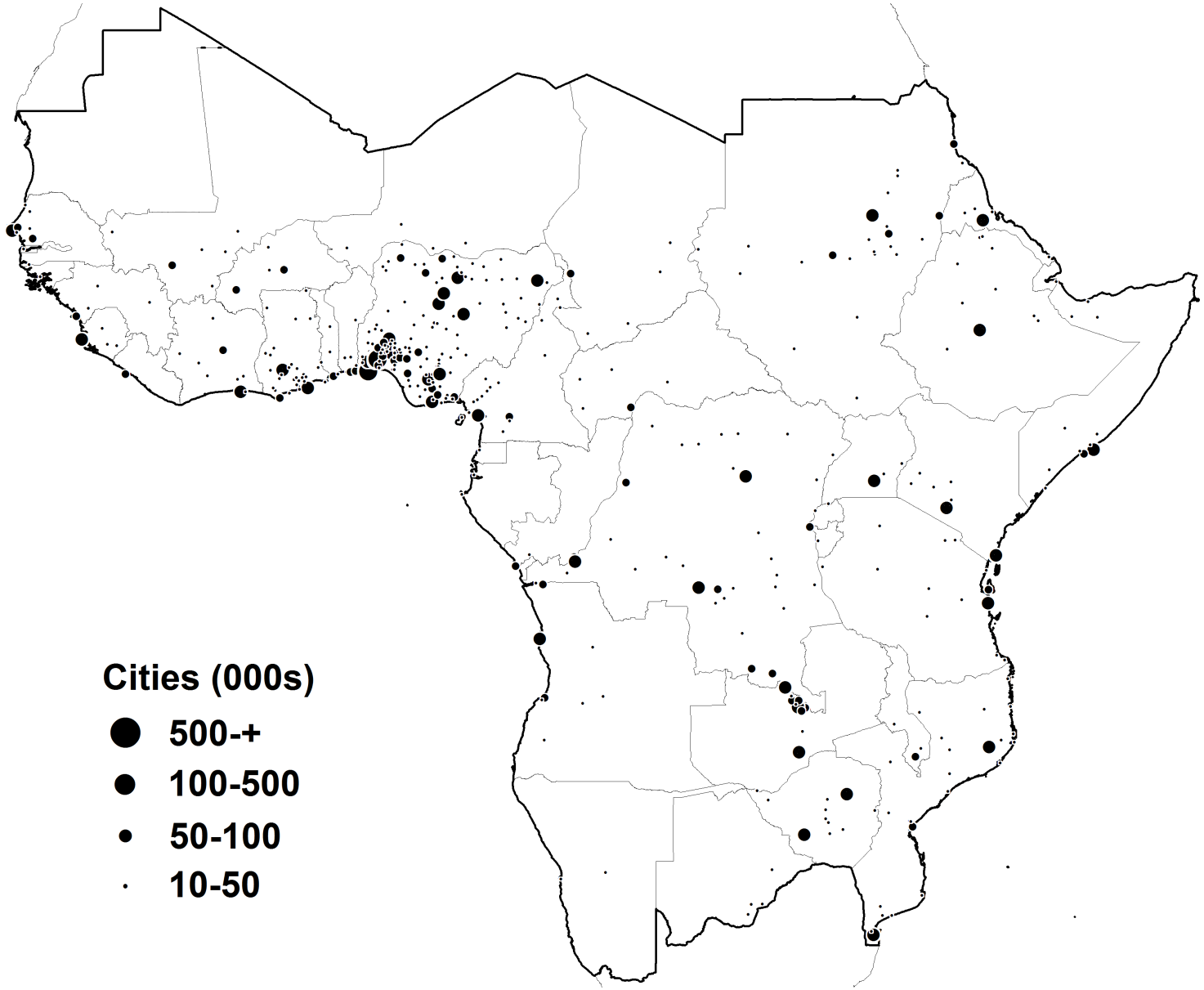


Data: Cities

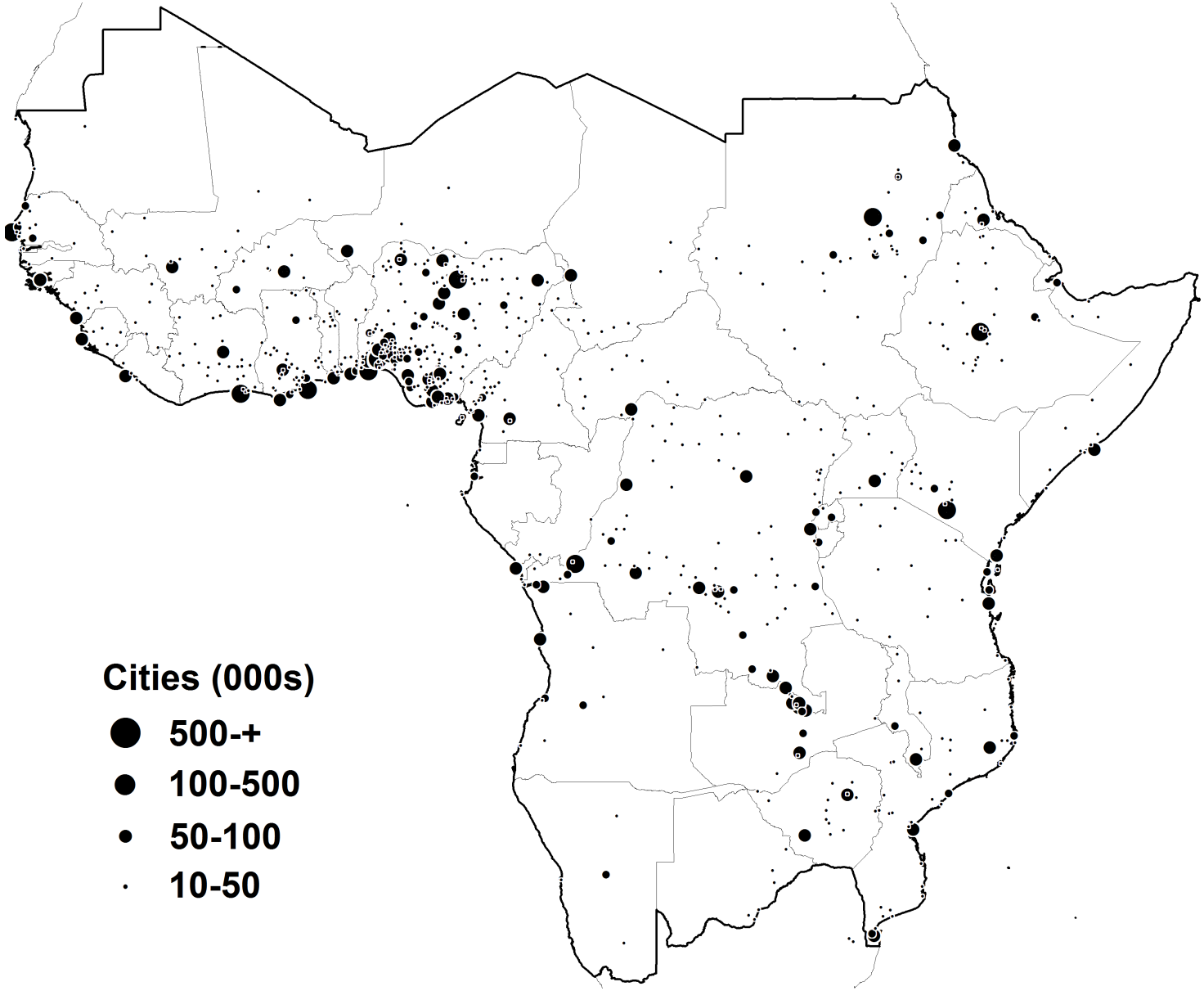
GIS database of cities:

- Population of localities ever above 10,000 inh. for the same 39 countries in 1960, 1970, 1980, 1990, 2000 and 2010
- Proxy for local economic development in the absence of other data (no land prices, no systematic rural populations before c. 1990, no night lights before 1992).
- Sources: *Africapolis I* and *II* for 33 countries + *Population Census* data for 6 countries (similar methodology)

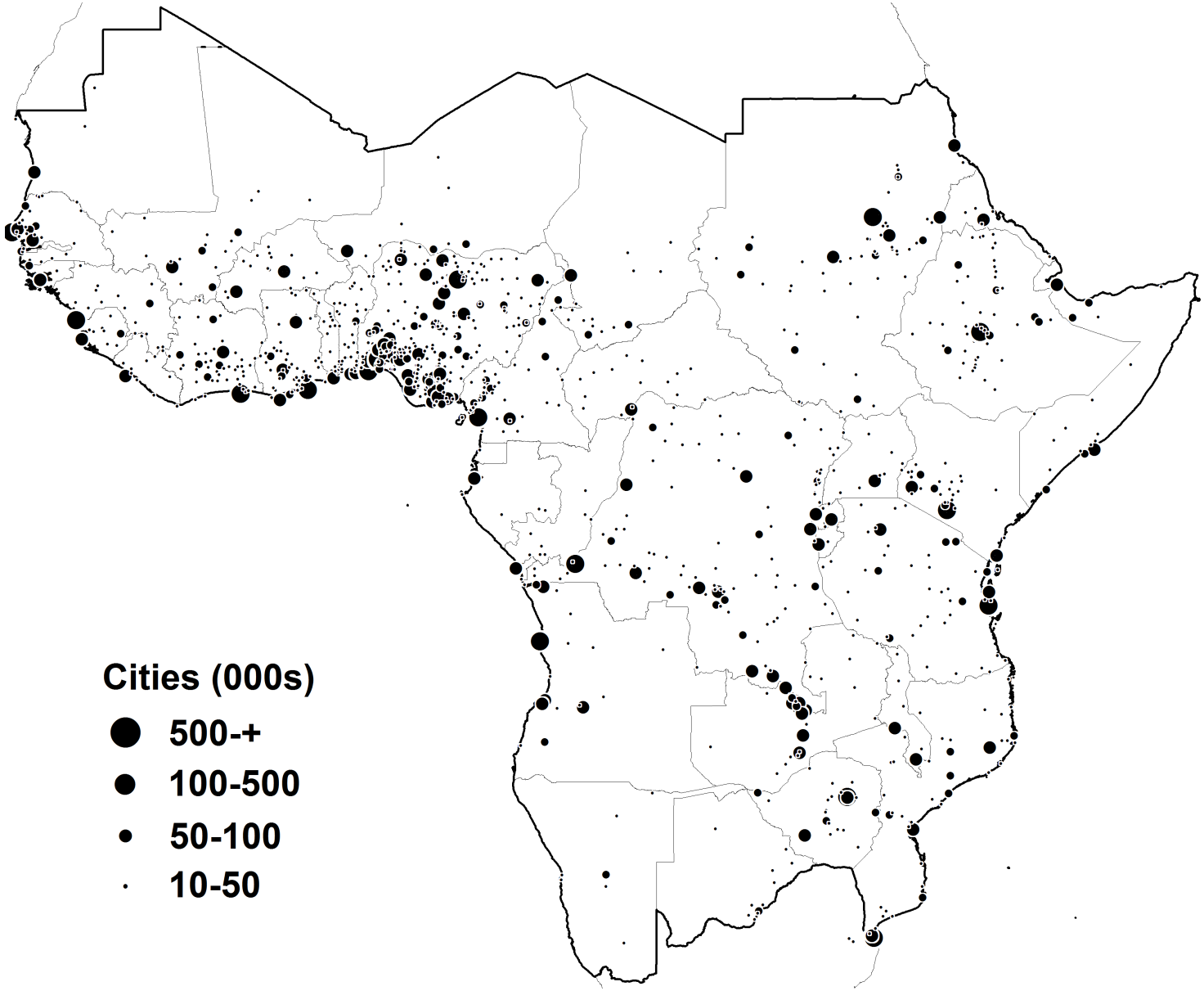
Cities ($\geq$ 10,000 Inh.) in 1960



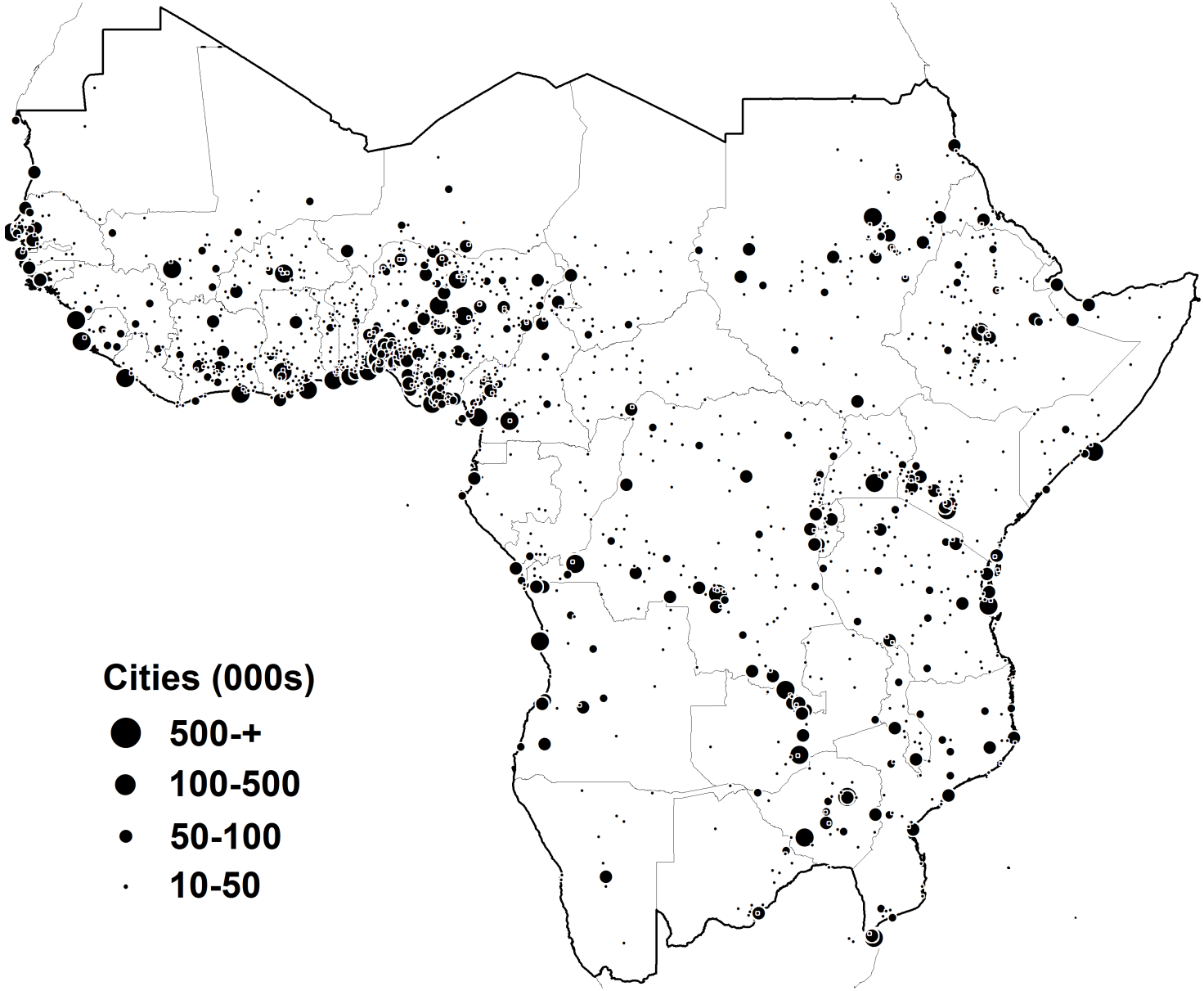
Cities ($\geq$ 10,000 Inh.) in 1970



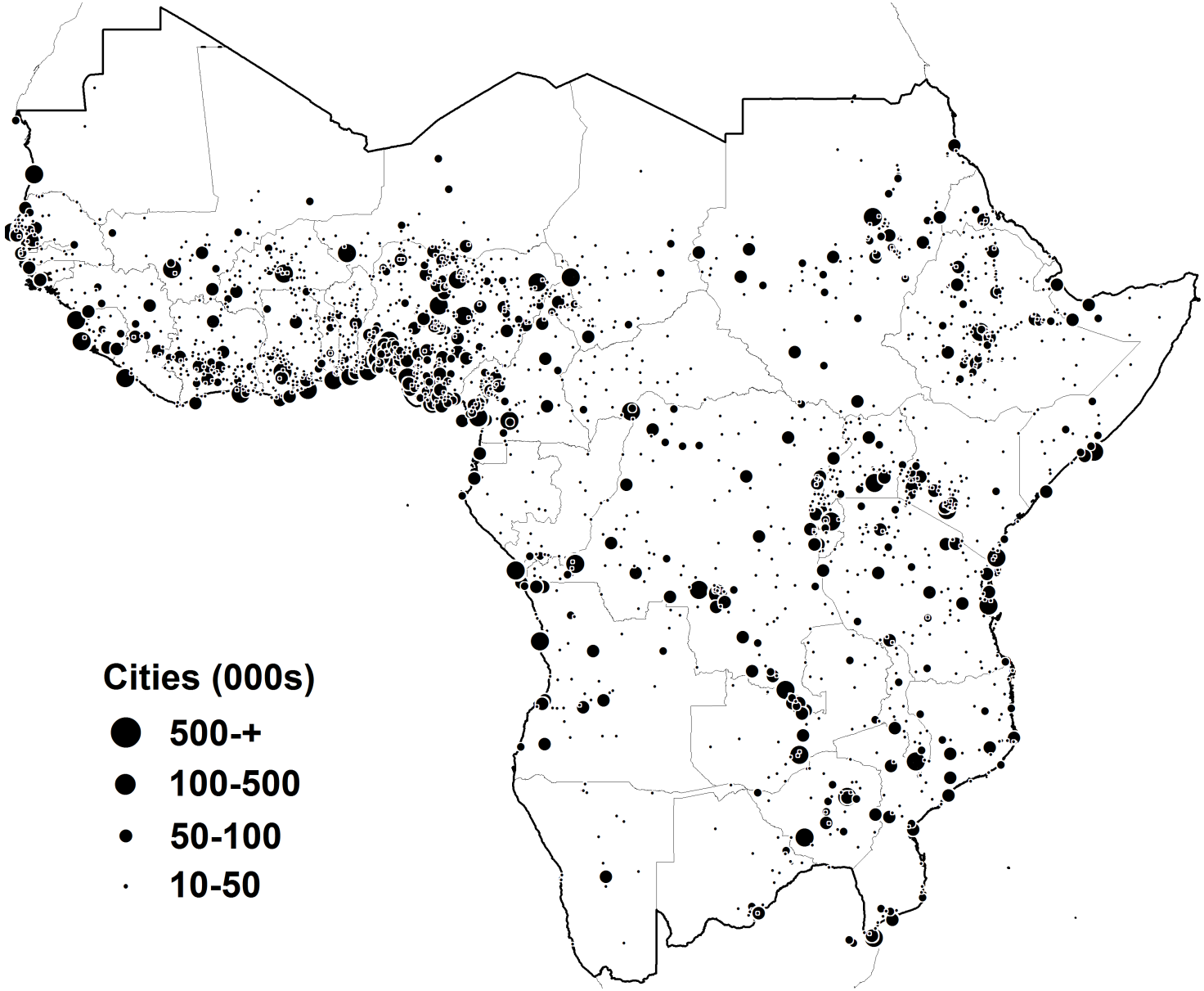
Cities ($\geq$ 10,000 Inh.) in 1980



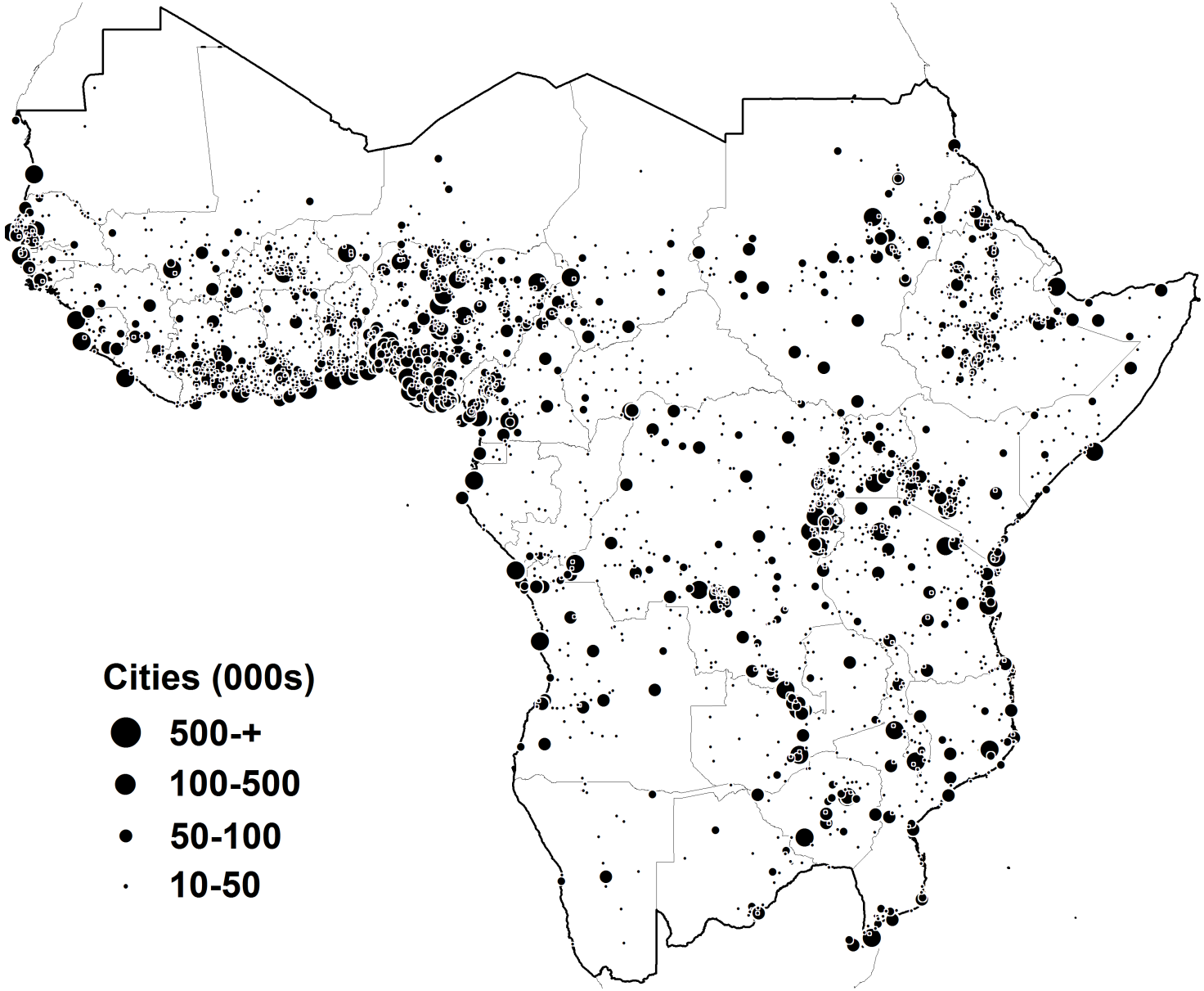
Cities ($\geq$ 10,000 Inh.) in 1990



Cities ($\geq$ 10,000 Inh.) in 2000



Cities ($\geq$ 10,000 Inh.) in 2010



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Unit of analysis

- Grid squares: 0.1x0.1 degree (˜11x11 km; computational constraints)
- Select the best (lowest-cost) road in the cell
- Sum of city populations within cell (98 of 2,879 populated cells have multiple cities)

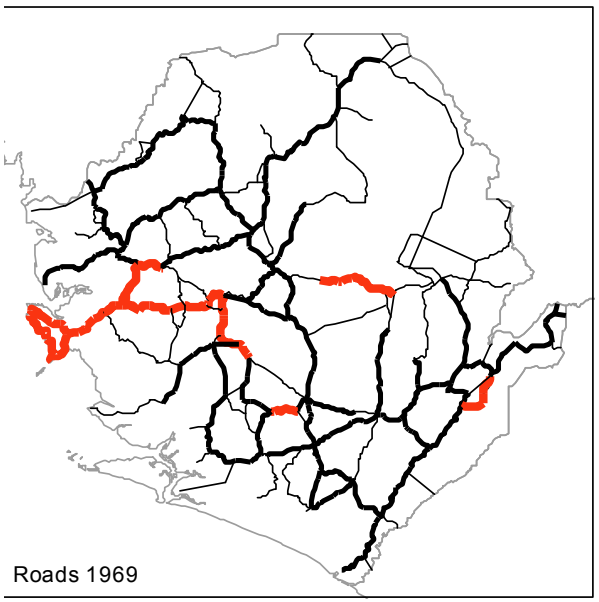
Sample

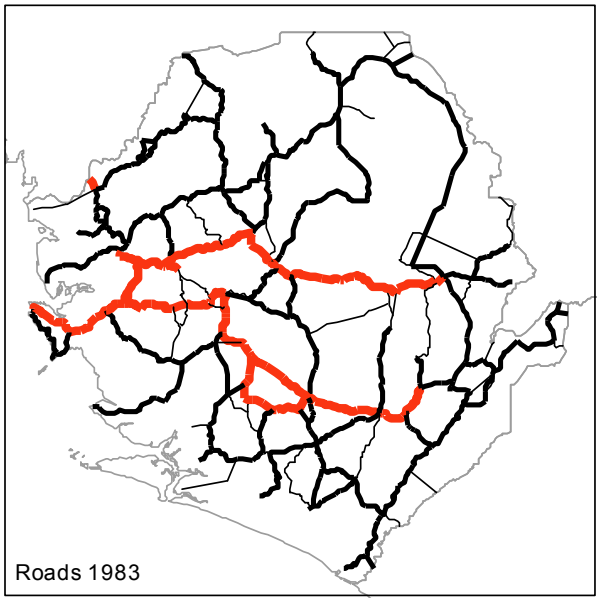
- Full sample: 5,906 city-years for 2,127 cities (>10,000 in at least two years)
  - 2010: 2,119
  - 2000: 1,514
  - 1990: 1,094
  - 1980: 746
  - 1970: 433
  - 4,725 city-years for 2,126 cities when including two lags

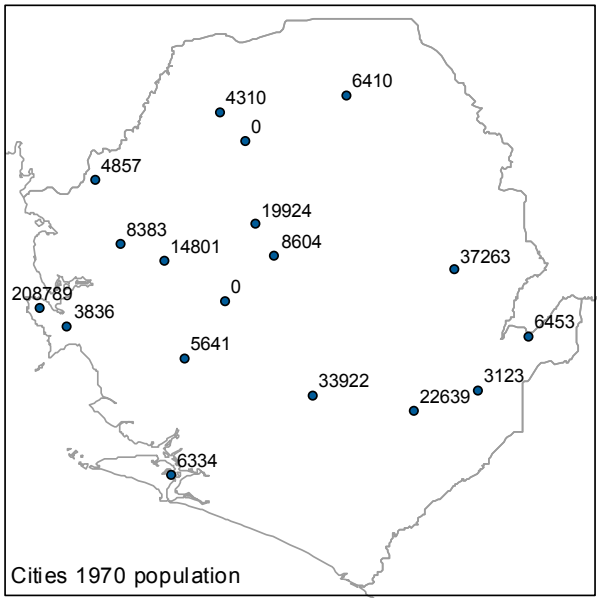
Defining Market Access

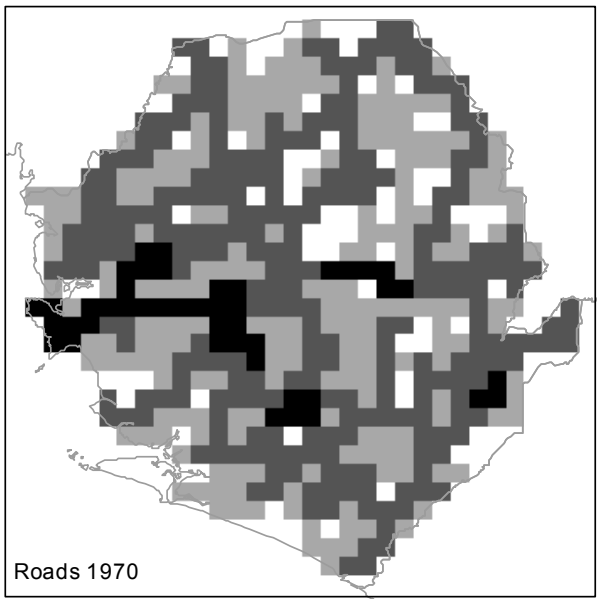
- Roads matter beyond the cities they pass through
- First cut: how many people can I reach within a two hour journey from e.g. 1818 H St NW?
  - How many more can I reach if I build a new road or rail?
- **Market access** generalizes this for concentric rings of travel time:
  - weighted sum of all people outside the city
  - weights decline with travel time (far places count less)
- Building/improving roads increases market access by reducing travel time
  - Building roads to bigger cities increases market access more
- We don't consider congestion (lack of data, conceptual issues)

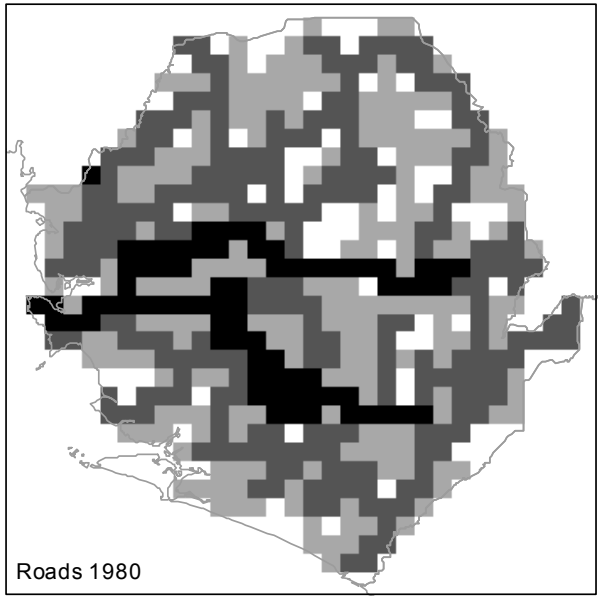
Example for Sierra Leone, 1970-1980

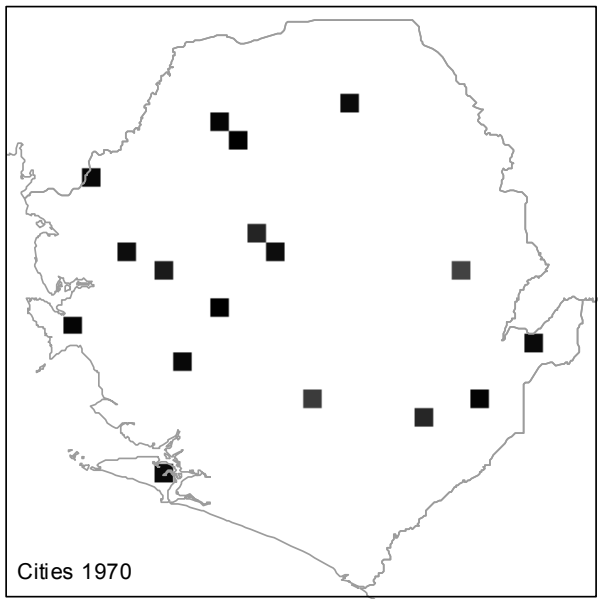












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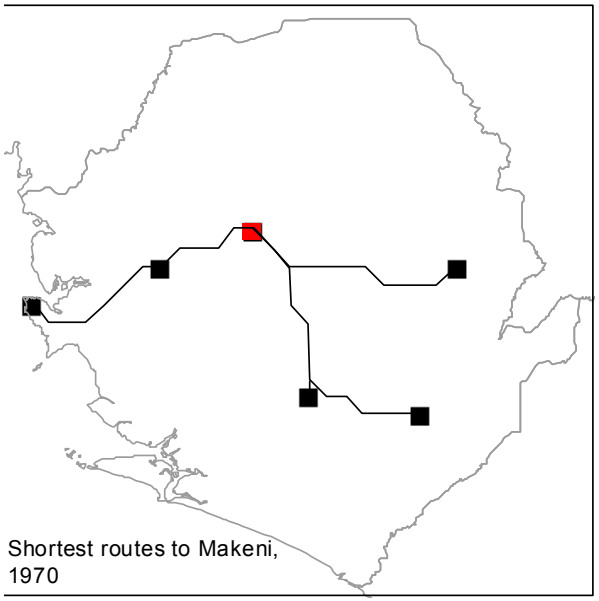
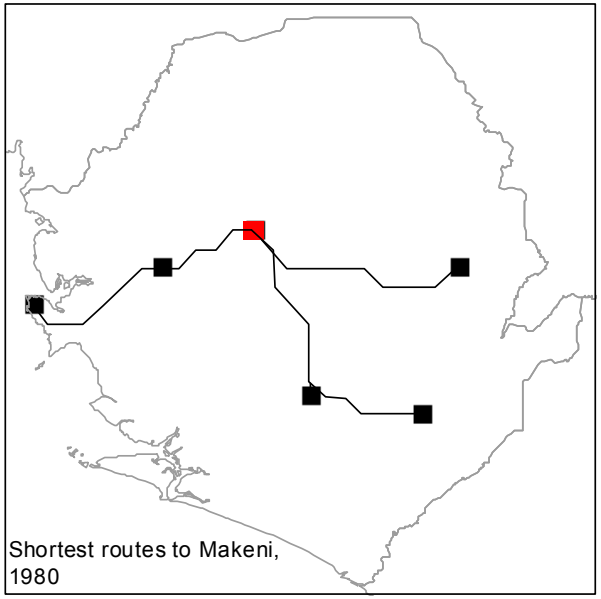
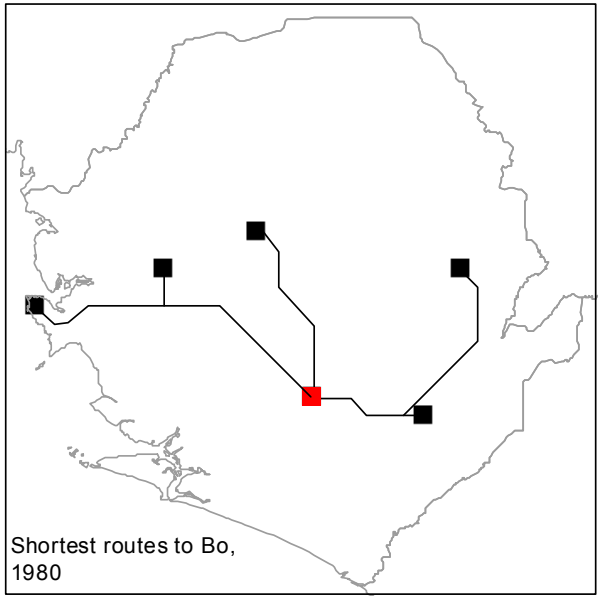
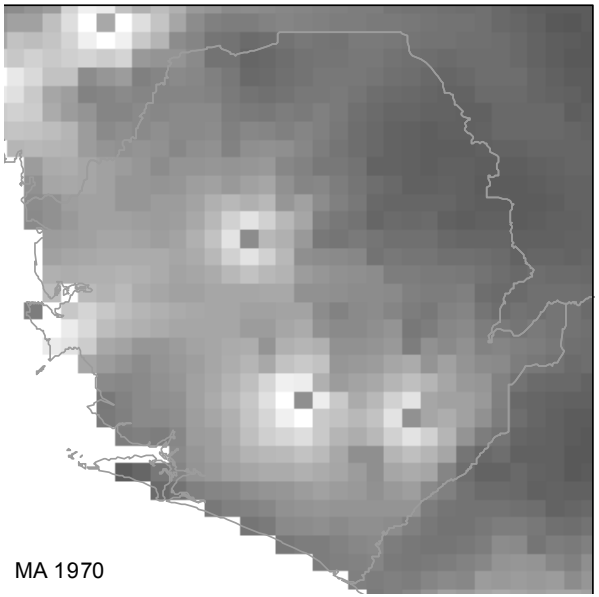
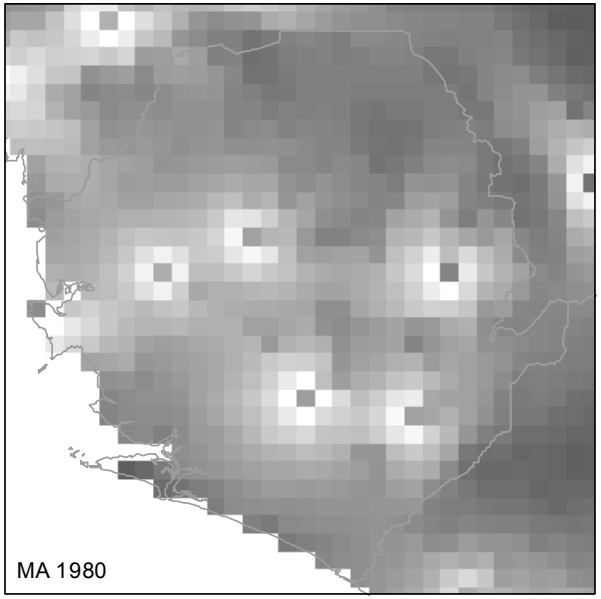
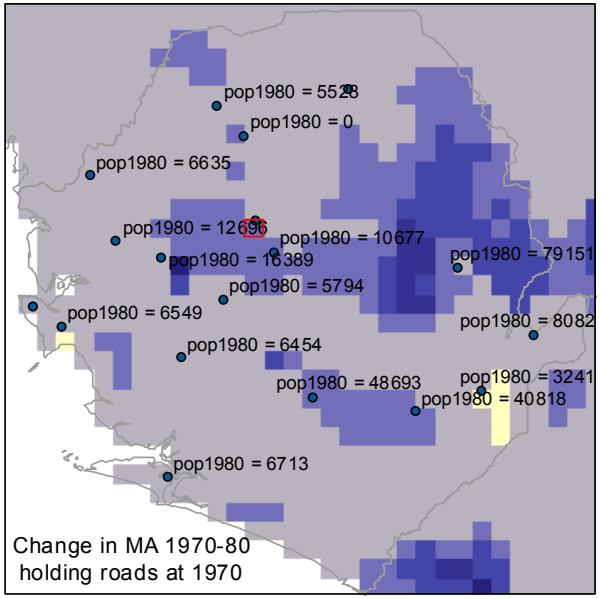




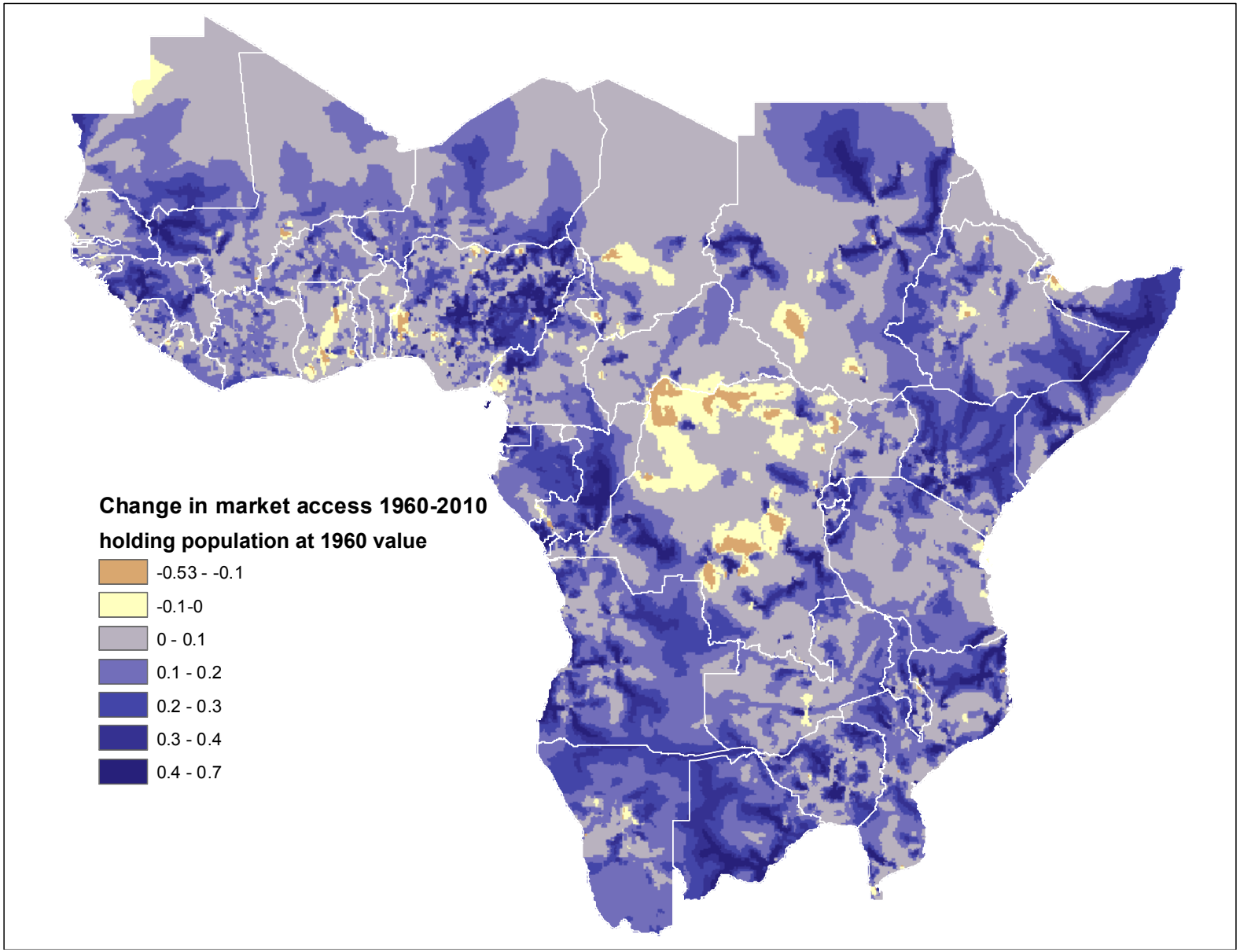








Change in market access due to road changes, 1960-2010



Problems with determining causal impacts of road building on city population using market access

- Reverse causality
  - Governments may build roads to places they expect to grow rapidly in the future
    - High growth misattributed to roads (overestimation)
  - Governments may build roads to places they expect to lag
    - Low growth misattributed to roads (underestimation)
- All cities in a region may grow rapidly together for a reason unrelated to roads
  - e..g. a local resource boom drives growth in my city and my neighbors
  - Neighbors' population increases my market access
  - But I don't grow *because of* my neighbors' growth
- Our indicator of market access may be badly measured

Proposed solutions

- Control for any *national-level* shocks that might be driving road building and city growth in a given decade (country-year fixed effects)
  - e.g. coups
- Control for smoothly varying spatial shocks (year-specific spatial poynomials)
  - e.g. climate
- Control for lagged population
  - mean reversion

Proposed solutions

- Use restricted variation in market access change (instrumental variable)
  - Only changes due to roads, not population
  - Only changes to roads "far" away from the city in question
    - more than 50 km; more than 100 km;
    - outside country
    - example: Lagos-Ibadan road (Nigeria) affects market access for Cotonou (Benin)
  - valid if these "far" away roads are built for reasons unrelated to the city in question

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Table 3: OLS estimates of the effect of market access on urban population, 1960–2010

	(1)	(2)	(3)	(4)	(5)
Dep. variable:	$(\Delta^{t}_{t-10}$ ln urban population$)/100$				
$\Delta^{t}_{t-10} \ln MA$	1.34***	1.27***	1.58***	1.63***	1.50***
	[0.32]	[0.32]	[0.35]	[0.44]	[0.38]
$\Delta^{t-10}_{t-20} \ln MA$		1.02***	1.23***	1.55***	1.11***
		[0.24]	[0.26]	[0.34]	[0.30]
$\Delta^{t-20}_{t-30} \ln MA$			0.81***	0.89***	0.79***
			[0.23]	[0.29]	[0.27]
$\Delta^{t-30}_{t-40} \ln MA$				0.27	
				[0.23]	
$\Delta^{t+10}_{t} \ln MA$					0.67
					[0.49]
Overall effect	1.34***	2.29***	3.62***	4.33***	3.40***
$(t-40$ to $t)$	[0.32]	[0.45]	[0.59]	[0.83]	[0.65]
Observations	5,906	5,472	4,725	3,630	2,607
Adj. R-squared	0.26	0.22	0.19	0.18	0.22

Notes: Each column is a separate OLS regression of Δ ln urban

Table 4: Market access and urban population: additional controls and instrumental variables, 1960–2010

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Control:	*Instrumental variable (IV):*					
		Own cost	Exclude 5	Exclude 10	Exclude 15	Exclude 20	Foreign	Non-neighbor
Δ_{t-10}^{t} MA	1.58***	1.52***	2.98***	4.59***	5.75*	7.22*	1.79	8.43*
	[0.35]	[0.39]	[1.00]	[1.76]	[2.95]	[4.09]	[1.89]	[4.60]
Δ_{t-20}^{t-10} MA	1.23***	1.24***	3.28***	5.76***	7.34***	9.01***	1.73	-2.49
	[0.26]	[0.29]	[0.87]	[1.59]	[2.46]	[3.13]	[1.43]	[2.66]
Δ_{t-30}^{t-20} MA	0.81***	0.83***	2.57***	3.38**	4.60**	4.07**	1.09	2.06
	[0.23]	[0.24]	[0.86]	[1.39]	[1.95]	[1.92]	[1.12]	[1.70]
Overall effect	3.62***	3.58***	8.83***	13.74***	17.69***	20.30***	4.61*	8.00*
($t-30$ to t)	[0.59]	[0.65]	[1.89]	[3.31]	[4.64]	[5.77]	[2.38]	[4.82]
IV F-Stat			114	41.86	17.41	6.940	15.10	4.026

Summary of Average Effects

- Naive effect of a 100% change in market access: $\approx$ 1% - 1.5% per decade for three decades (total 30-year effect: 3-4%).
- **Better identified effect: $\approx$ 5–18% over 30 years.**
- Concentrated in first two decades (i.e. decade of construction and following decade)
- No measurable effect in fourth decade.
- Source of growth: rural areas or other cities? To be considered...

Comparison to literature

- Somewhat smaller than railroads in the 19th century US using similar method (Donaldson & Hornbeck 2015): ≈20–35%.
- Other contexts are too
- **Contextual differences:**
  - Not a transportation revolution like in the 19th century US. Railroads already existed in Africa before roads (and poor roads existed before good roads).
  - Migration costs likely higher at least for large distances.
  - Context of lower economic growth.

Heterogeneous Effects?

- Heterogenous effects? Focusing on space right now.
- We classify the cities into two groups depending on:
  - High vs. low initial city size
  - High vs. low initial market access
  - Near vs. far from coast, borders, largest cities

  etc.

  and see if the effect of a same change in road market access varies across the two groups.
- This will allow us to test various existing theories in trade and urban economics.

Heterogeneous Effects?

- No consistent robust effects for any of them
- Instruments get weaker.
- **Still work in progress**

Conclusion

- Study the effects of road construction and market access on city population growth in Sub-Saharan Africa in 1960-2010.
- New panel data set on road surface and city population for 39 African countries every ten years in 1960-2010.
- Average effect of a 100% change in market access $\approx$ 5-18%. Effect concentrated in first 3 decades.
- Still exploring the heterogeneous spatial and temporal effects of the same road investments.