Source: https://www.un.org/Depts/Cartographic/map/profile/mekong.pdf

Spatial Analysis of the Greater Mekong Subregion for Sustainable Development

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Evolution of <u>spatial developments</u> in the GMS

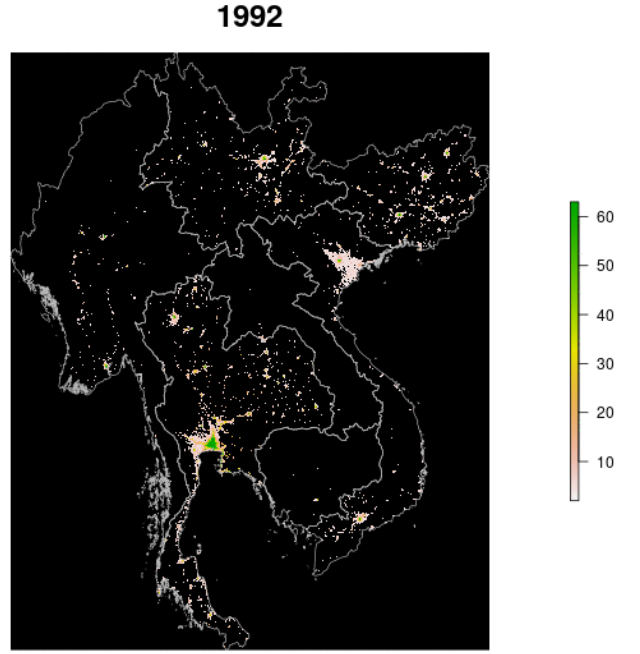
- Disaggregated regional data are **not** easily available from national statistics systems.
- Available census and survey data are **not** sometimes comparable.
- Timing of the census and surveys may be **different**.

➔ We should look for better data.

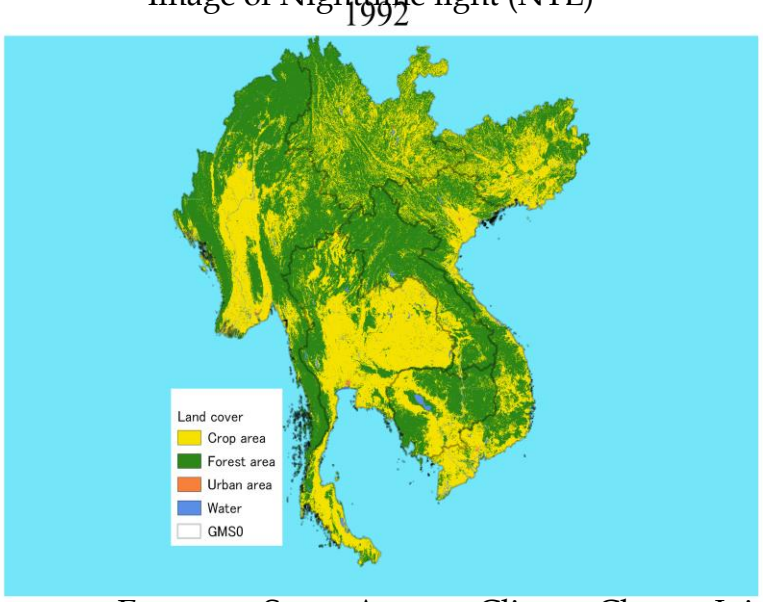
Solution: Look at the subregion from space

Remote sensing data is a set of picture data taken from satellites. Data is available from 1992

- **Night = Nighttime light (NTL)**
  - Nighttime light is a good indicator for socio-economic activities
  - Large clusters of NTL are found in Bangkok, Hanoi, Ho Chi Min city, and Kunming.
  - Small clusters of NTL are found in Cheng Mai, Vientiane, Phnom Penh, Mandalay and Yangon.
- **Day = Land cover (Land utilization)**
  - Urban area for human settlements
  - Crop area for agricultural activities
  - Forest area for natural endowments
- **<u>Comparability</u> and <u>consistency</u> is guaranteed**
  - Data period is from 1992 to 2012.
    - Data for 2012-2018 shall be added sooner than later.

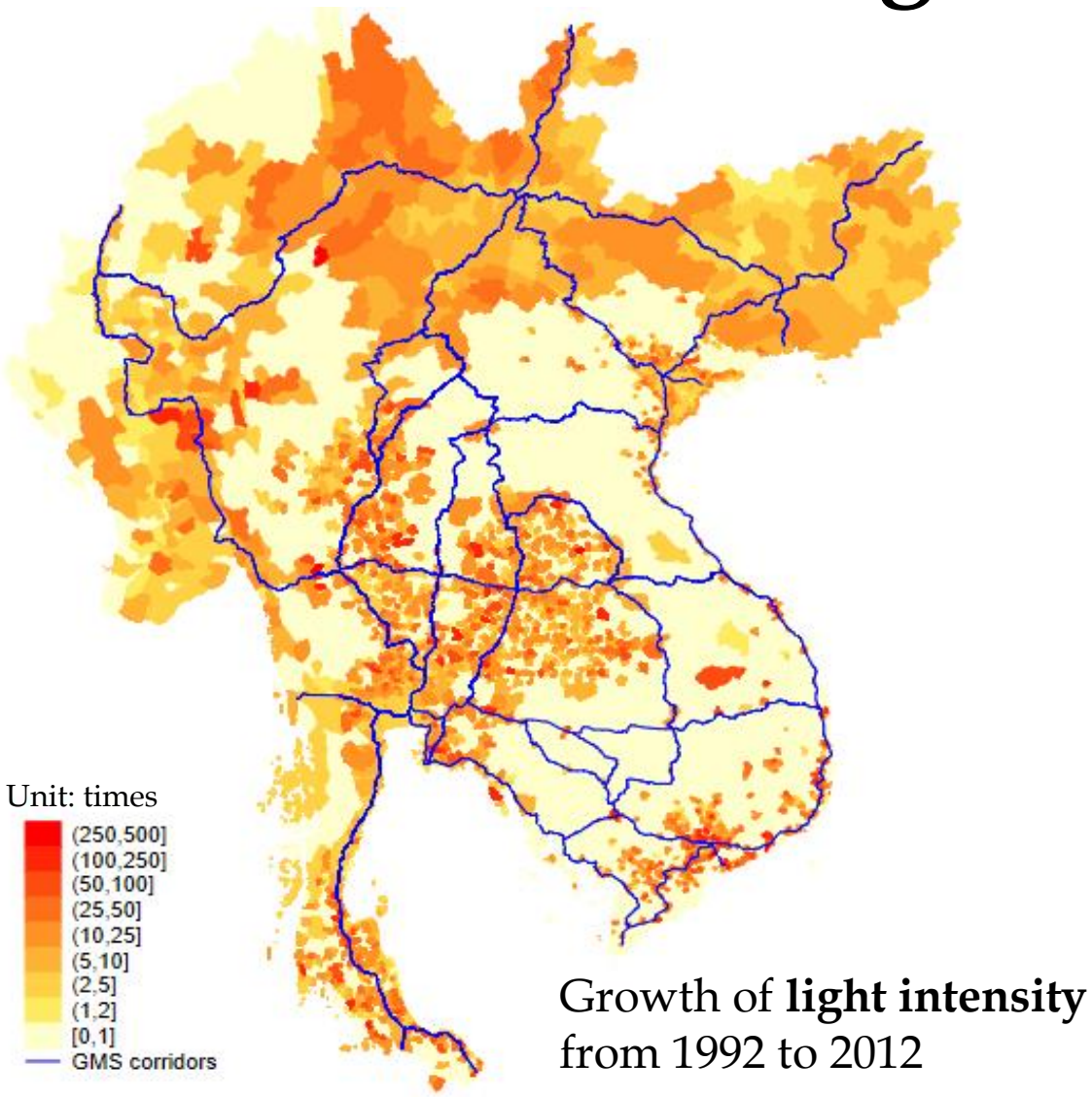


Data source: Defense Meteorological Satellite Program – Operational Linescan System
Image of Nighttime light (NTL)

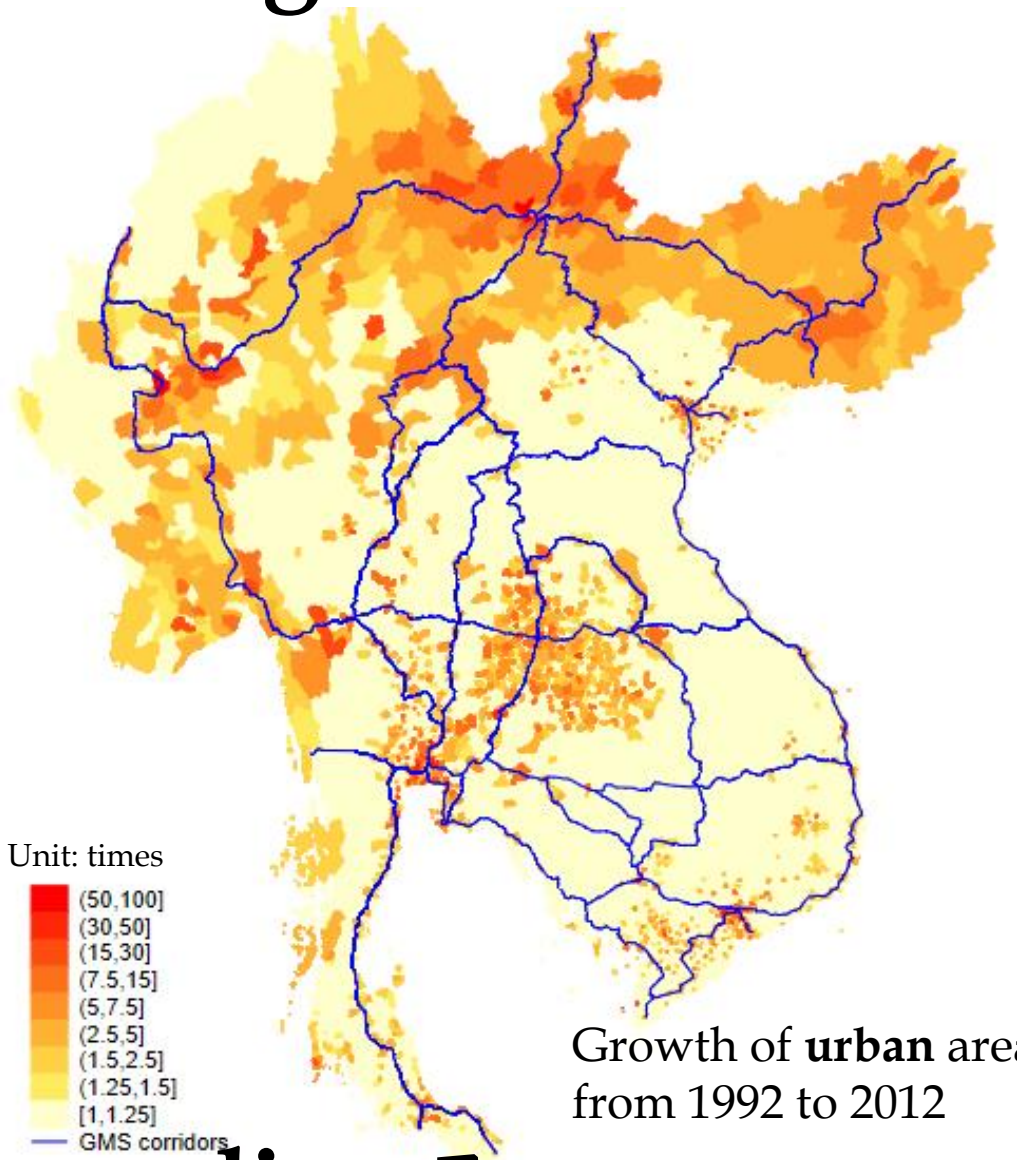


Data source: European Space Agency, Climate Change Initiati
Image of land cover

↘GMS is becoming brighter at night



Growth of **light intensity** from 1992 to 2012



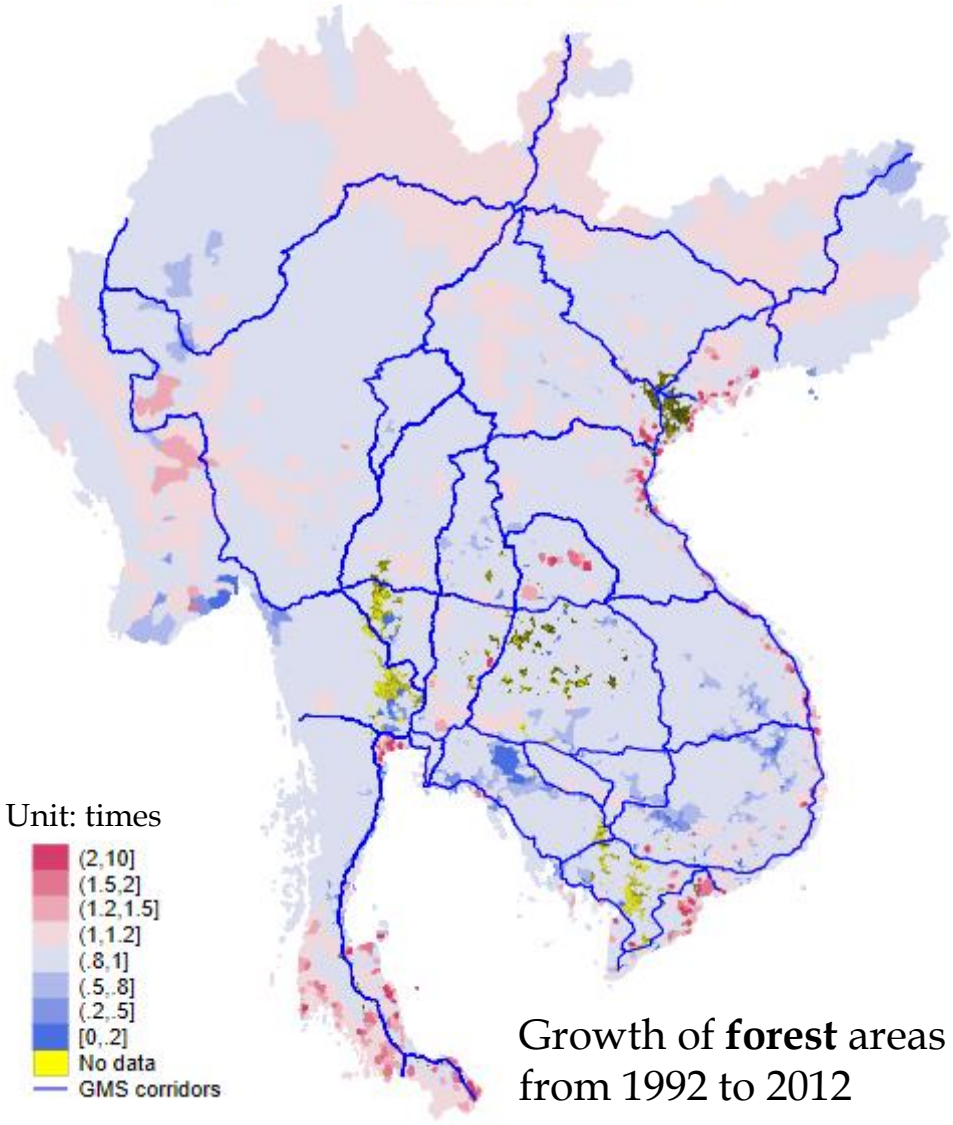
Growth of **urban** areas from 1992 to 2012

Urban areas are expanding⇗

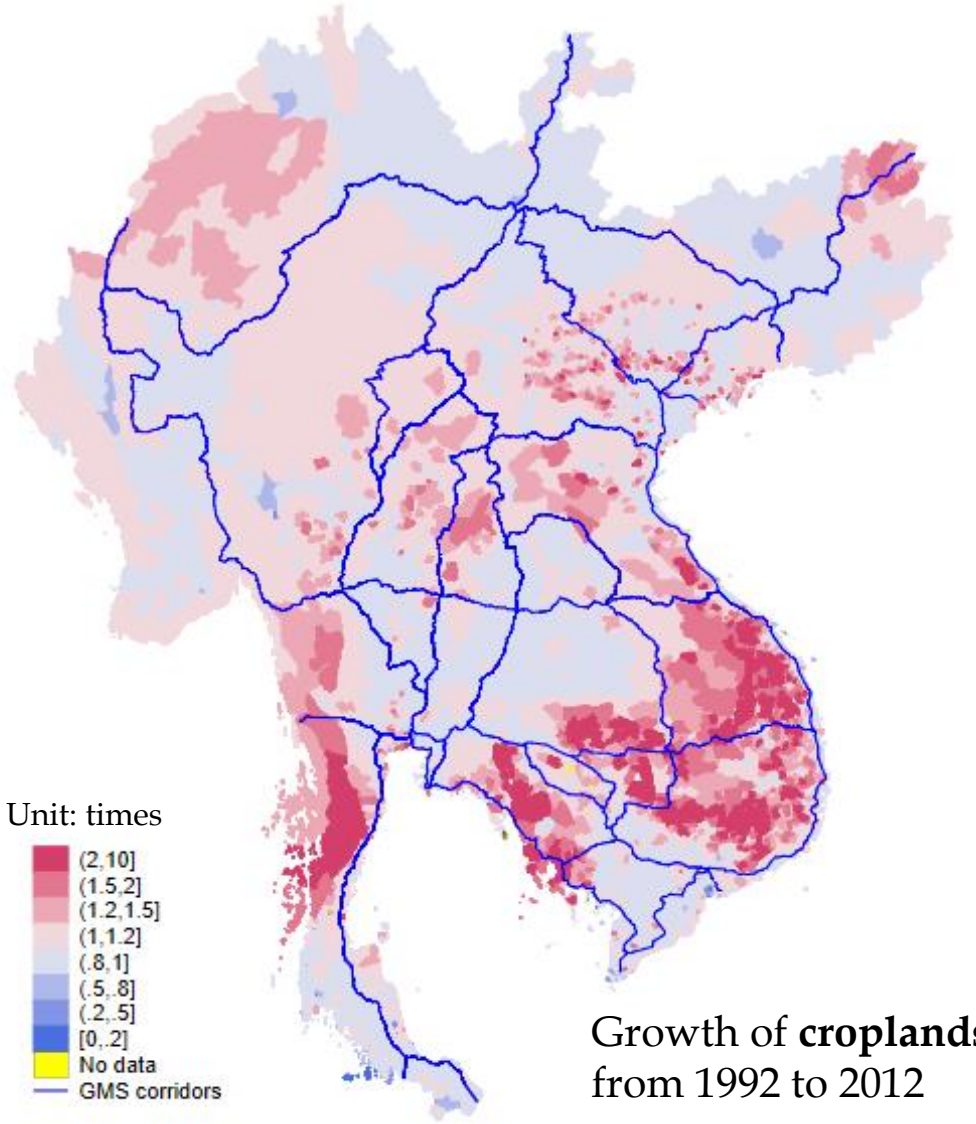
Data source: Defense Meteorological Satellite Program - Operational Linescan System

Data source: European Space Agency, Climate Change Initiative

↘Deforestation: Forest areas are shrinking



Growth of **forest** areas
from 1992 to 2012



Growth of **croplands**
from 1992 to 2012

Crop areas are expanding in forest areas⇗

Data source: European Space Agency, Climate Change Initiative

What were the drivers of the growth?

- What are impacts of Economic Corridors?
  - There are endogeneity issues between the major roads and economic growth.
  - Faber (2014) examined the impacts of Chinese trunk highway by estimating the growth of Regional GDP and the highway networks. He employed IVs for the highway networks as *least cost path tree networks* and *shortest distance networks* of major cities.

$$\ln\left(y_{ip}^{2006}\right) - \ln\left(y_{ip}^{1997}\right) = \gamma_p + \beta Connect_{ip} + \eta X_{ip} + \epsilon_{ip}$$

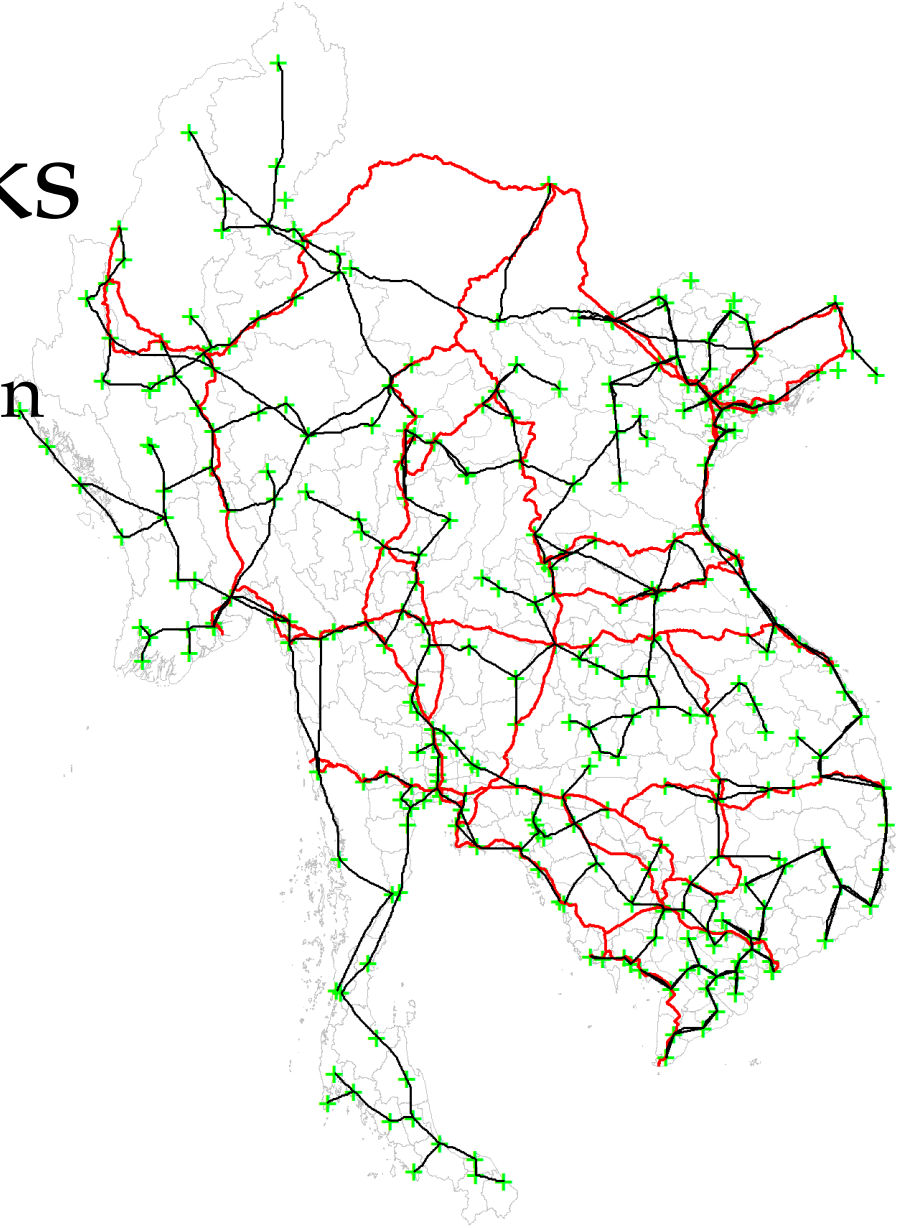
  - Following Faber (2014), we estimate the changes of GMS in relations to the economic corridors.
    - We construct *least cost path tree networks* for **major points** (capital cities, major secondary cities, ports and border customs).
    - We employ remote sensing data such as nighttime lights, and land cover (urban, forest, croplands)

Faber, B. (2014) Trade Integration, Market Size, and Industrialization: Evidecefrom China's National Trunk Highway System, Rev. Econ. Stud., 81, pp1046-1070.

Least cost path tree networks

- Taking the physical geography of elevation and land covers as given, we calculate the optimal route between any points of concerns. Then we apply the algorithm to connect all targeted nodes on a single continuous network with least total cost.

- Major points in GMS for Economic Corridors planning were **capital cities**, **major secondary cities, ports** and **border customs**, shown as the green markers.



Black line: Least Cost Path Tree Network
Red line: Economic Corridors

What are the impacts of Economic Corridors?

- Following Faber (2014), we estimate the growth of NTL, and the changes in land utilization by linking to the corridor networks. We construct *least cost path networks* by constructing from the terrain data.

$$ln\left(NTL_{ri}^{2012}\right) - l\,n\left(NTL_{ri}^{1992}\right) = \alpha + \beta Corridor_{ri} + \eta X_{ri} + \epsilon_{ri}$$

  - Control variables include area size, share of urban land use as of 1992, a dummy variable for major points, and the shortest distance to the nearest major point.
  - Country-fixed effects are always included.
  - Standard errors are clustered at province/state level (adm1).
  - Two samples: **with full observation** and **with restricted observations 30km or more apart from major points**.

Results for Nighttime lights

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	Growth of lit area				Growth of lit intensity			
Estimation Method	OLS	OLS	IV: 2nd stage	IV: 2nd stage	OLS	OLS	IV: 2nd stage	IV: 2nd stage
Economic Corridor Dummy	-0.160***		-1.800***	-2.226***	-0.074		-0.872	-0.968
	(0.035)		(0.601)	(0.770)	(0.055)		(0.530)	(0.638)
Least Cost Path Tree Network Dummy		-0.144***				-0.070*		
		(0.032)				(0.037)		
Area size	0.455***	0.458***	0.462***	0.479***	0.330***	0.331***	0.334***	0.348***
	(0.021)	(0.021)	(0.026)	(0.029)	(0.029)	(0.028)	(0.029)	(0.030)
Share of urban as of 1992	0.326**	0.330**	0.459***	0.570***	-0.441**	-0.438**	-0.376*	-0.325
	(0.127)	(0.132)	(0.150)	(0.176)	(0.204)	(0.205)	(0.225)	(0.230)
Log(distance to the nearest major point)	-0.046	-0.037	-0.186***	-0.153	-0.146***	-0.142***	-0.214***	-0.205**
	(0.040)	(0.040)	(0.072)	(0.099)	(0.052)	(0.052)	(0.064)	(0.083)
Fixed effects at Country level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,369	8,369	8,369	7,876	8,369	8,369	8,369	7,876
R-squared	0.310	0.310			0.195	0.195		
First-stage *F* statistic of excluded instrument			17.7	13.05			17.7	13.05
(p-value)			(0.000)	(0.000)			(0.000)	(0.000)

Notes: The numbers in parentheses report standard errors robust to clustering within province/state leve (adm1); the constant is not reported; ***, **, and * indicate the statistical significance at the 1%, 5%, and 10% level, respectively.

Sample size:

First three estimations for each variable use **full-sample.**

The last estimation use restricted sample for the regions whose distance from the nearest major point(capital cities, major secondary cities, ports and border customs) is more than 50kms.

Results for Land utilization

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent variable	Growth of urban area (land use)				Growth of forest area (land use)				Growth of crop land (land use)			
Estimation Method	OLS	OLS	IV: 2nd stage	IV: 2nd stage	OLS	OLS	IV: 2nd stage	IV: 2nd stage	OLS	OLS	IV: 2nd stage	IV: 2nd stage
Economic Corridor Dummy	0.819***		2.715	4.146	0.007		0.155	0.209	-0.017		-0.094	-0.278*
	(0.290)		(2.385)	(2.722)	(0.019)		(0.147)	(0.191)	(0.020)		(0.200)	(0.152)
Least Cost Path Tree Network Dummy		0.278				0.013				-0.008		
		(0.251)				(0.013)				(0.017)		
Area size	-0.480***	-0.491***	-0.465**	-0.473**	-0.005	-0.005	-0.003	0.001	0.095***	0.095***	0.094***	0.081***
	(0.180)	(0.182)	(0.181)	(0.204)	(0.008)	(0.008)	(0.008)	(0.009)	(0.018)	(0.018)	(0.017)	(0.015)
Share of urban as of 1992	-4.730***	-4.801***	-4.627***	-4.673***	-0.886***	-0.888***	-0.959***	-0.983***	-0.711***	-0.714***	-0.689***	-0.676***
	(0.569)	(0.570)	(0.634)	(0.735)	(0.107)	(0.109)	(0.136)	(0.154)	(0.080)	(0.079)	(0.105)	(0.099)
Log(distance to the nearest major point)	-0.001	-0.057	0.156	-0.061	0.043***	0.044***	0.050***	0.076***	-0.019	-0.019	-0.022	-0.042**
	(0.208)	(0.203)	(0.285)	(0.368)	(0.011)	(0.011)	(0.014)	(0.021)	(0.015)	(0.015)	(0.016)	(0.020)
Fixed effects at Country level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,934	3,934	3,934	3,649	12,773	12,773	12,773	10,732	18,845	18,845	18,845	16,454
R-squared	0.053	0.050			0.030	0.030			0.096	0.096		
First-stage F statistic of excluded instrument			18.99	15.11			29.40	19.08			34.26	24.64
(p-value)			(0.000)	(0.000)			(0.000)	(0.000)			(0.000)	(0.000)

Notes: The numbers in parentheses report standard errors robust to clustering within province/state leve (adm1); the constant is not reported; ***, **, and * indicate the statistical significance at the 1%, 5%, and 10% level, respectively.

Sample size:
First three estimations for each variable use **full-sample.**
The last estimation use restricted sample for the regions whose distance from the nearest major point(capital cities, major secondary cities, ports and border customs) is more than 50kms.

Econometric Results

- **Nighttime lights**
  - The growth were not restricted to the regions with economic corridors.
  - **The regional spreads of lit areas** were widely observed in rural regions, regardless of the presence of economic corridors.
- **Land utilization**
  - Urban growth was observed at the regions on the Economic Corridors but not statistically significant. Though the variations in changes in forests and crop areas are larger in the regions on the Economic Corridors, results were not statistically significant.
- **In summary**
  - Results didn't show the clear impacts of Economic Corridors.
  - The growth of regions may not have been strongly related to the Economic Corridors.

Policy Implications

- **Integrated spatial planning for agro-forest, industry, and environment is desirable**
- **Integrated spatial planning requires regional cooperation and coordination within and among countries.**
- **For such planning, developing regional indicators based on remote sensing data should be helpful.**

⇒ **Observations on nighttime light in the GMS:**

- NTLs were highly concentrated in urban area, and were spatially spreading to rural.
- Growth of NTLs in rural areas was faster

⇒ **Observations on landcover data in the GMS:**

- Urbanization was very fast.
- Deforestation was widely observed. Forests were converted into crop lands.

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Further points for discussions

- **The results may be interpreted as the regional convergence.**
  - As the rural regions exhibited growth in the number of lit areas and lit intensity, the gaps between rural and urban may be shrunken.
- **There are two thresholds hindered in the nighttime data.**
  - Specifically, DMSP-OLS has 63 scales, but it is pointed out the blurredness and non-preciseness. Also, higher values are top-coded and small values cannot be captured. These shall affect our results.
- **Landcover data has various other dimensions.**
  - We focused on urban, forest, and croplands because these categories can bring us the most meaningful policy implications. However, there are other uses as well. Thus, only focusing on these elements would lead us over-evaluation of one of the directions.

Summary statistics

	Regions with Major points	Other regions	Region whose distance to major points is less than 50kms	Region whose distance to major points is more than 50kms
Growth in lit area	0.760	0.857	1.279	0.728
	(0.955)	(0.764)	(0.985)	(0.943)
Growth in lit intensity	1.623	2.105	2.209	1.587
	(0.973)	(0.650)	(0.982)	(0.960)
Growth in urban area	3.250	3.769	2.994	3.272
	(5.436)	(2.422)	(4.264)	(5.510)
Growth in croplands	1.055	0.962	1.164	1.039
	(0.495)	(0.294)	(0.715)	(0.451)
Growth in forest area	0.936	0.866	0.896	0.944
	(0.357)	(0.336)	(0.266)	(0.371)
area size	3.290	2.852	3.744	3.225
	(1.588)	(1.310)	(1.209)	(1.624)
Ratio of Urban area in 1992	0.0371	0.0531	0.00447	0.0418
	(0.163)	(0.168)	(0.0398)	(0.174)
Ln(distance to the nearest major point)	4.688	1.206	3.335	4.872
	(0.728)	(0.347)	(0.539)	(0.543)
Observations	19274	36	2397	16913

Note: the numbers in parentheses are standard dev.

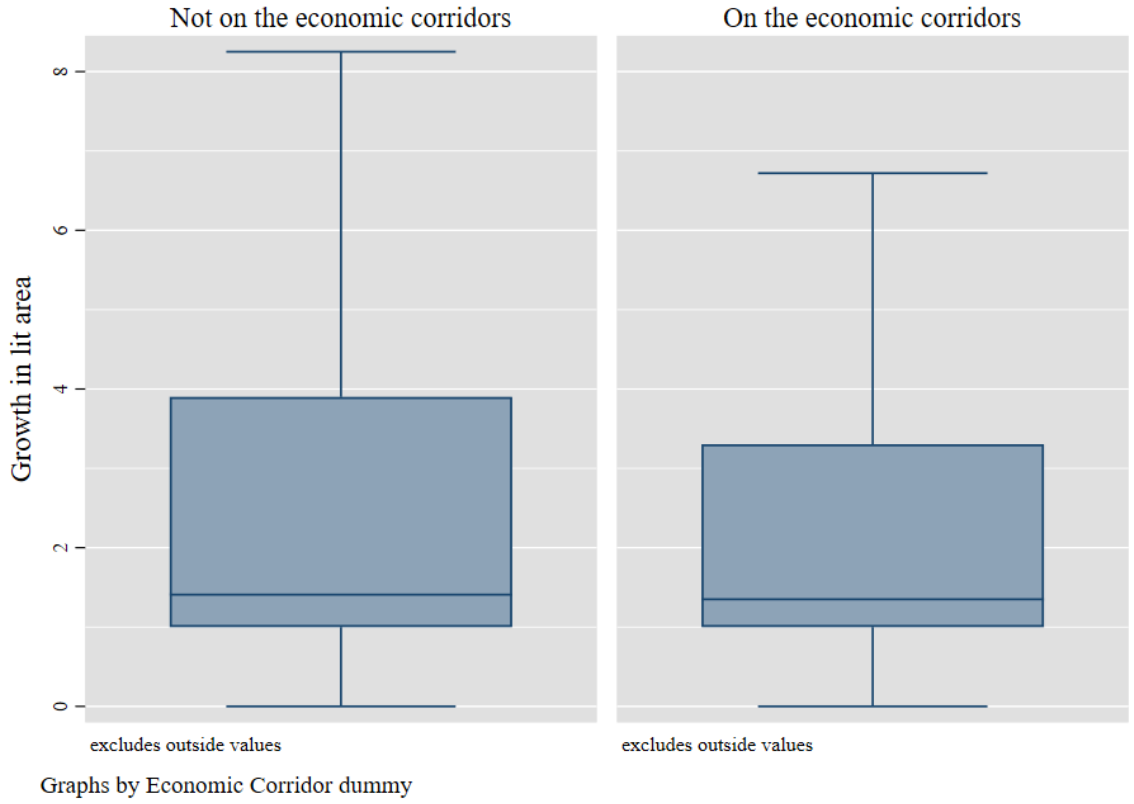
Summary statistics in detail

	1992				2012			
	Regions with Major points	Other regions	Region whose distance to major points is less than 50kms	Region whose distance to major points is more than 50kms	Regions with Major points	Other regions	Region whose distance to major points is less than 50kms	Region whose distance to major points is more than 50kms
Number of lit area	7.385	5.139	2.834	8.025	26.36	17.31	15.65	27.86
	(33.67)	(8.476)	(13.05)	(35.56)	(101.2)	(19.92)	(61.32)	(105.4)
Sum of lit intensity	67.32	38.61	20.20	73.94	341.5	326.8	185.6	363.6
	(349.1)	(70.31)	(110.1)	(369.9)	(1309.3)	(426.7)	(769.2)	(1366.1)
Urban area	0.216	0.153	0.0751	0.236	0.559	0.466	0.233	0.605
	(1.867)	(0.319)	(0.576)	(1.980)	(3.961)	(0.534)	(1.511)	(4.188)
Crop area	51.45	19.47	41.61	52.78	53.43	20.55	46.64	54.32
	(179.1)	(19.31)	(103.6)	(187.2)	(182.0)	(20.65)	(115.0)	(189.4)
Forest area	74.10	9.492	74.73	73.87	71.45	8.187	68.90	71.68
	(409.9)	(17.05)	(329.5)	(419.6)	(403.7)	(15.33)	(320.6)	(413.7)
Observations	19274	36	2397	16913	19274	36	2397	16913

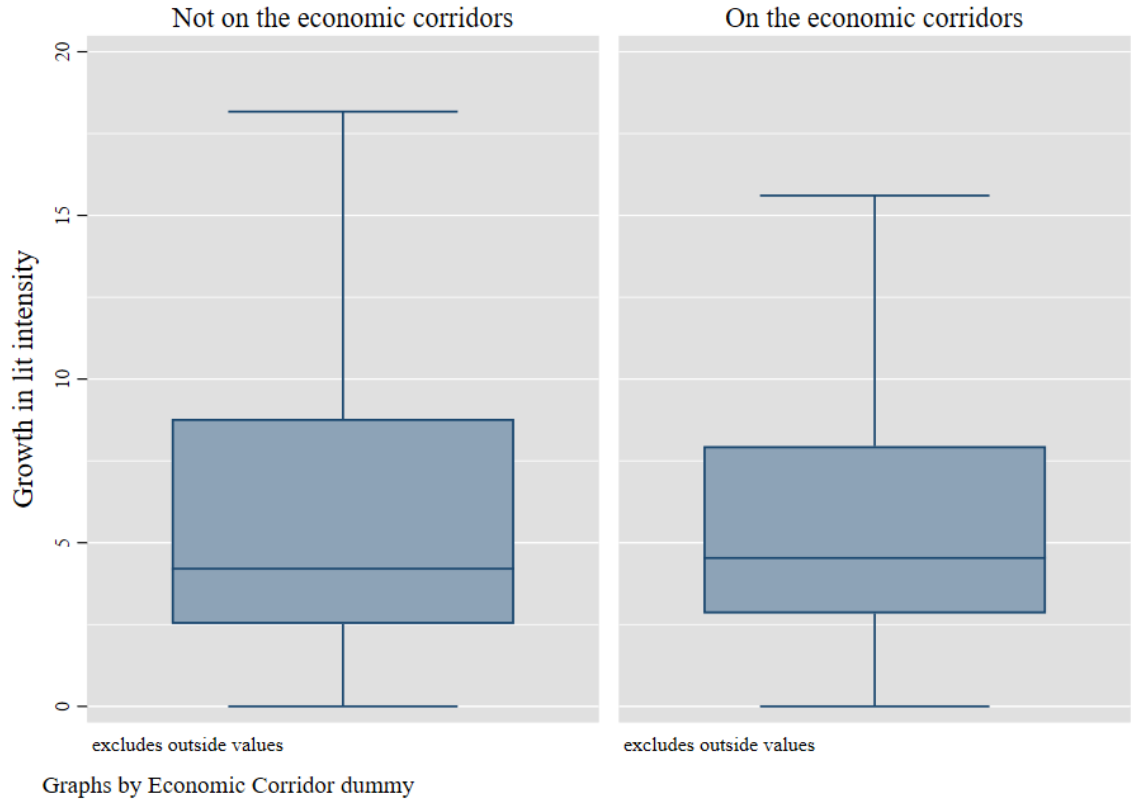
Notes: Total number of observations is 19310; the numbers in parentheses are standard dev.

Supplementary plots (not for presentation)

Lit area



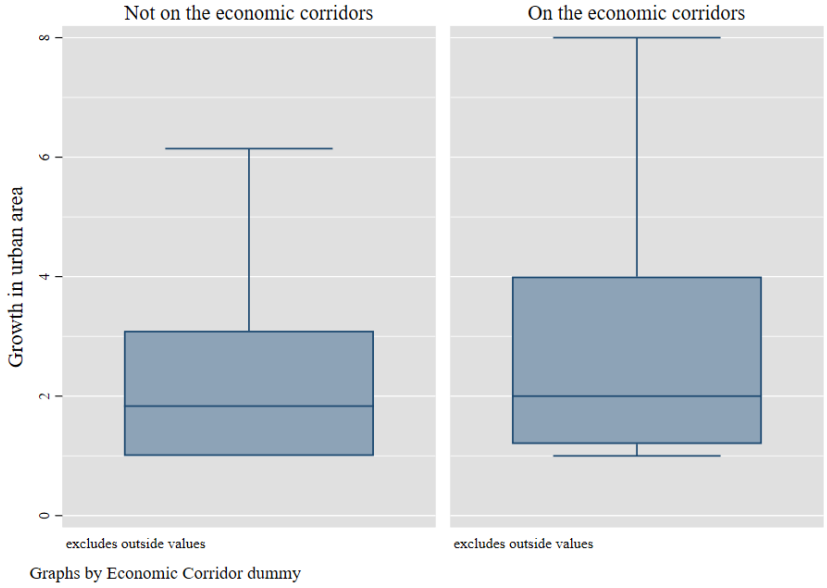
Lit intensity



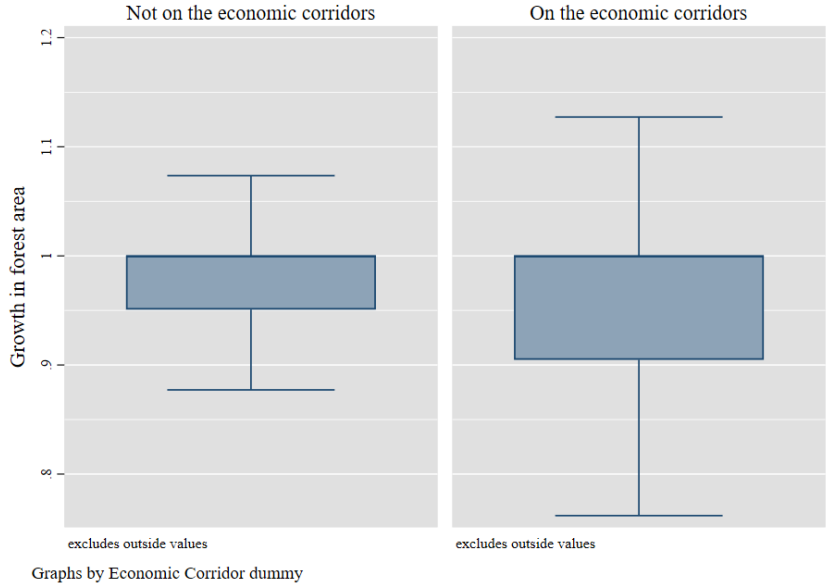
Left) Not on the economic corridors, Right) On the economic corridors

Supplementary plots (not for presentation)

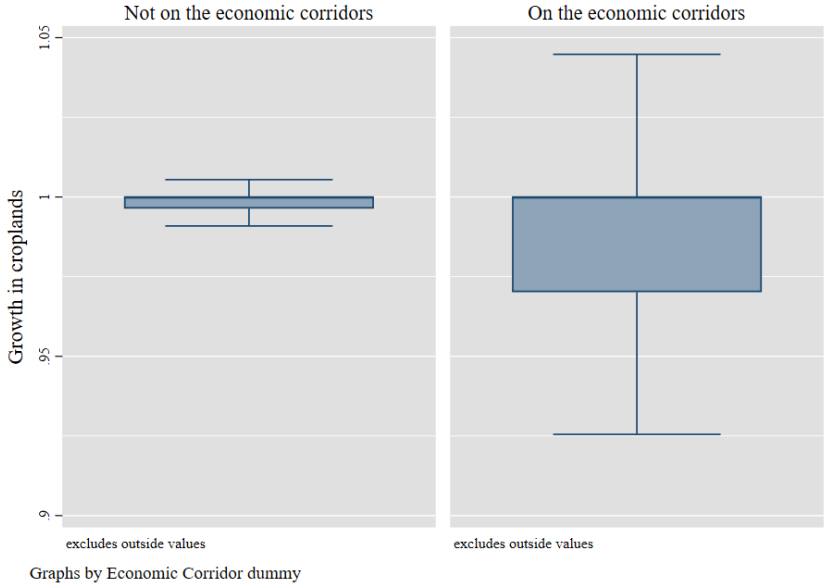
Urban area



Forest area



Crop area



Left) Not on the economic corridors, Right) On the economic corridors