# Geographically Informed Policy Response and Intervention

## *Modeling the Spatial Non-Stationarity of Poverty Determinants*

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# Outline

- Motivation
- Empirical Literature
- Global Cross-Country Regression
- Geographically Weighted Regression
- Policy Implications
- Q&A

# Motivation

- Moving from theory to praxis, we encounter enormous heterogeneity within member States (as the units of analysis) that may mask underlying processes

- Poverty/growth regressions with subnational data, while affording greater spatial precision, still yield a one-size-fits-all model

- Perhaps the construction and perpetuation of poverty is intrinsically different over space; can/should we assume parameter stationarity or should we explicitly test for it?

# Empirical Literature (1)

- Research literature preoccupied with the missing variable approach to poverty modeling
- Debates continue over the primacy of institutions v. geography; the role of trade liberalization, cultural cleavages, structural adjustment, demographic momentum, etc.
- However, the empirical literature relies without exception on the cross-country regression approach where we assume, implicitly, that there exists a universal construction of poverty

# Empirical Literature (2)

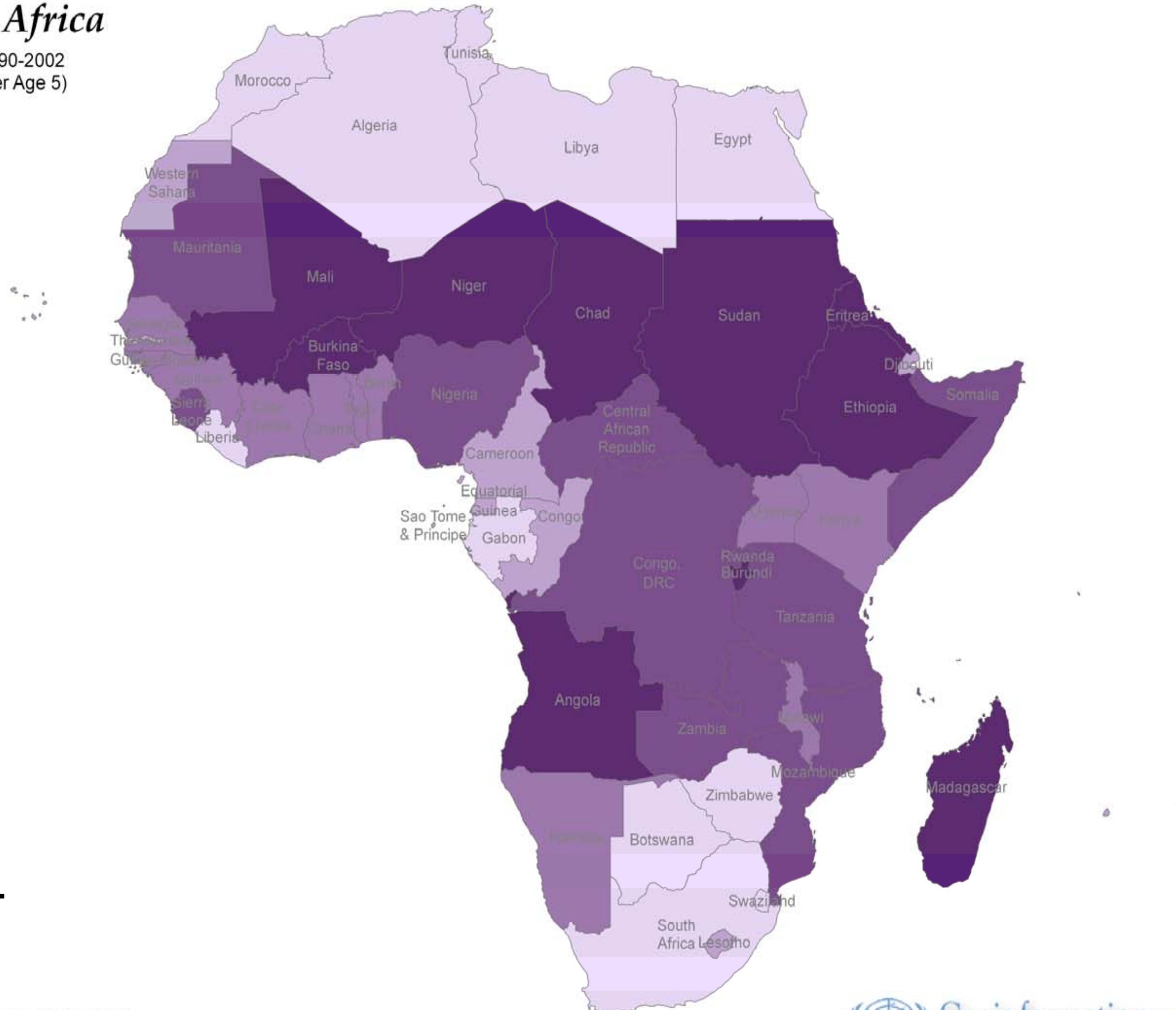
- Some poverty analysts are cognizant of tenuous universal explanations and appreciate the place specificity and scale dependencies of poverty:

The empirical relationship between poverty or inequality and indicators of development, such as economic growth, is typically examined in a cross-country regression framework. It is difficult, however, to control for the enormous heterogeneity which exists across countries; heterogeneity which may mask true relationships (Hentschel et al., 1998: 2).

[Variations in poverty determinants are] assumed to have the same effect in a poor country as in a rich country, in a primary-resource exporter as in a manufactures exporter, and in a country with well-developed institutions as in a country with underdeveloped institutions (Rodriquez, 2007: 2).

# *Spatial Determinants of Poverty in Africa*

Child Malnutrition, 1990-2002
(% Underweight Under Age 5)



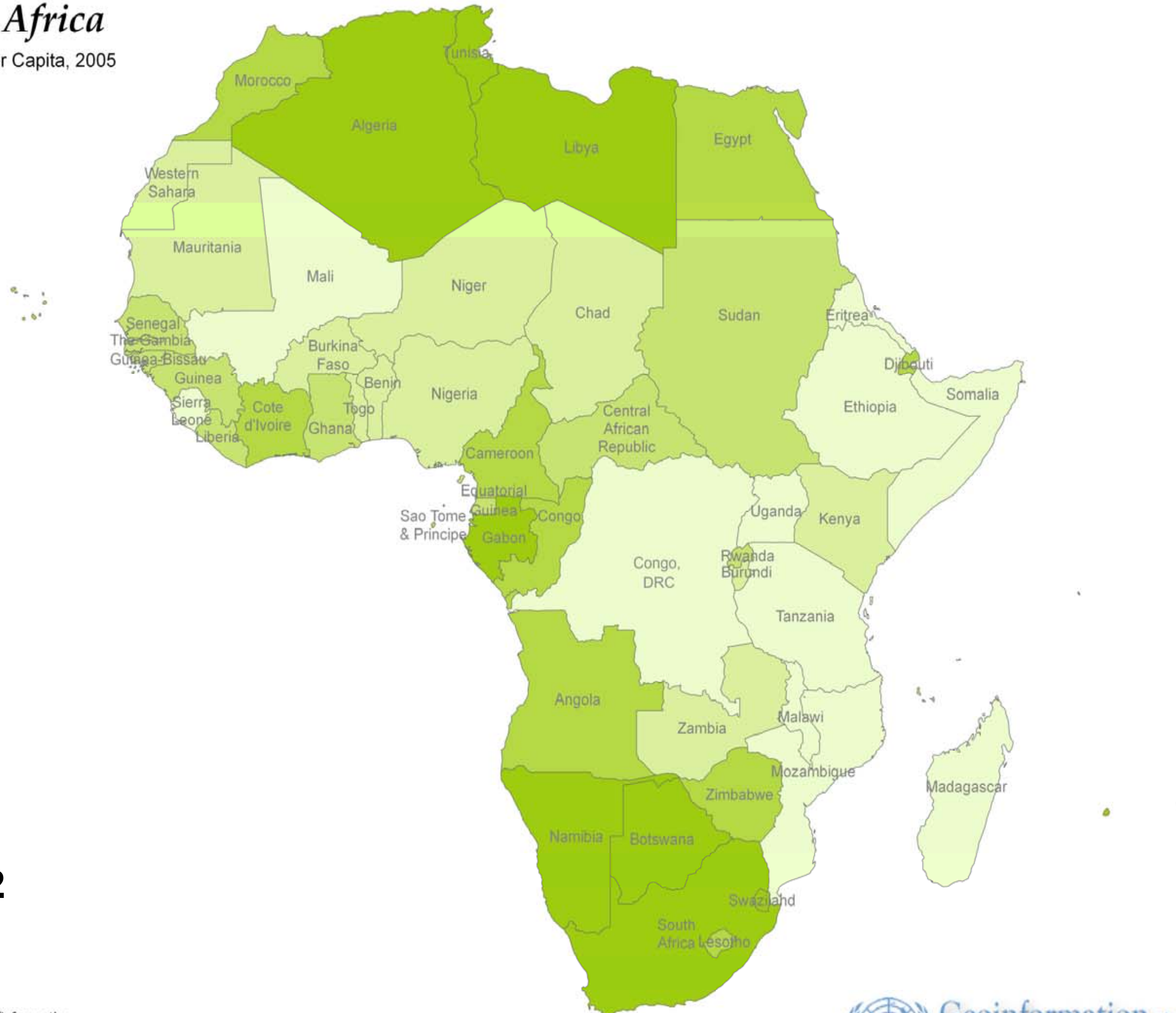

$I = 0.41$

Source: Gridded Underweight Children Raster (2.5')
from the Center for International Earth Science Information
Network (CIESIN) at Columbia University

Geoinformation at the UN Economic Commission for Africa
http://geoinfo.uneca.org

# *Spatial Determinants of Poverty in Africa*

Gross Domestic Product Per Capita, 2005

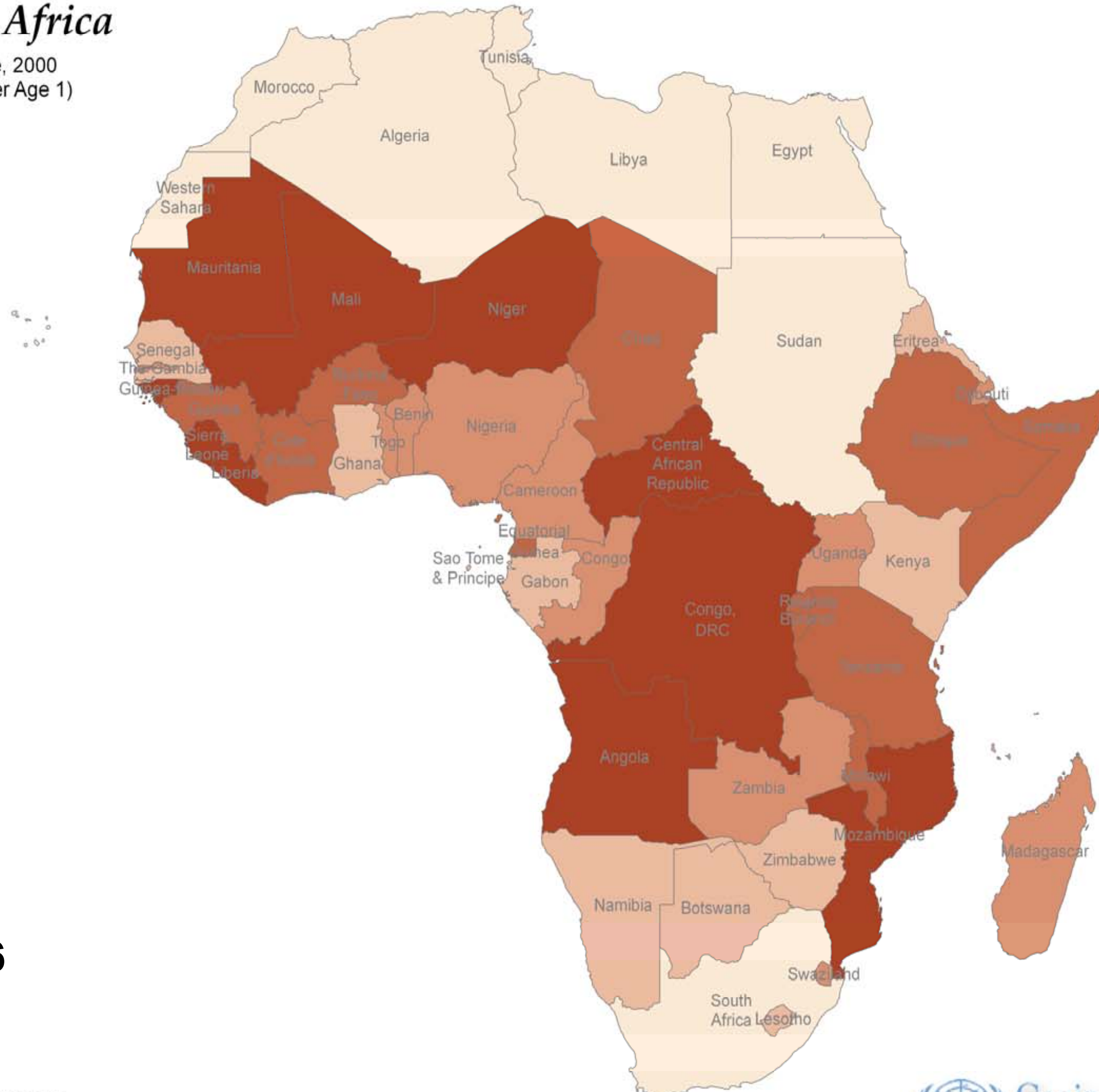



***I* = 0.32**

Source: Gridded GDP Raster (1/4°) from the Center for International Earth Science Information Network (CIESIN) at Columbia University

# *Spatial Determinants of Poverty in Africa*

Infant Mortality Rate, 2000
(Per 100 Infants Under Age 1)




$I = 0.36$

Source: Gridded IMR Raster (2.5') from the Center for International Earth Science Information Network (CIESIN) at Columbia University

Geoinformation at the UN Economic Commission for Africa
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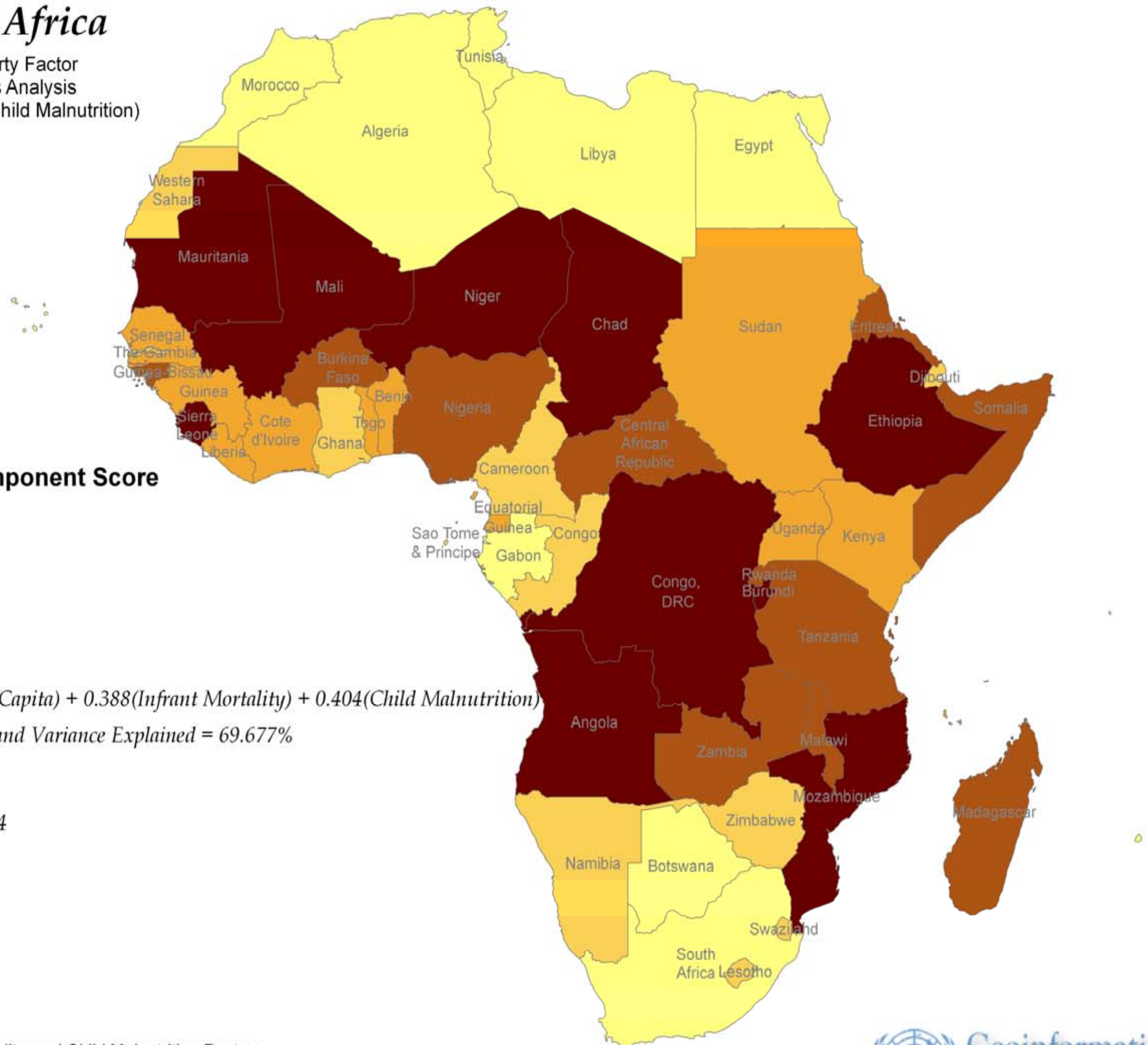
# *Spatial Determinants of Poverty in Africa*

Multidimensional Poverty Factor
(Principal Components Analysis
of GDP, Infant Mortality, and Child Malnutrition)




**Poverty Principal Component Score**

- -3.158 - -0.933
- -0.932 - -0.044
- -0.043 - 0.463
- 0.464 - 0.843
- 0.844 - 1.604

*Poverty*$_{PC}$ = -0.405(GDP Per Capita) + 0.388(Infrant Mortality) + 0.404(Child Malnutrition)

*Poverty*$_{PC}$ *Eigenvalue = 2.09 and Variance Explained = 69.677%*

*Poverty*$_{PC}$ *Communalities*

*GDP Per Capita = 0.718*
*Child Malnutrition = 0.714*
*Infant Mortality = 0.658*

Source: Gridded GDP, Infant Mortality, and Child Malnutrition Rasters from the Center for International Earth Science Information Network (CIESIN) at Columbia University

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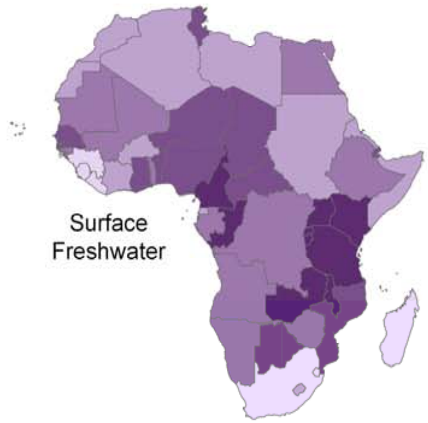
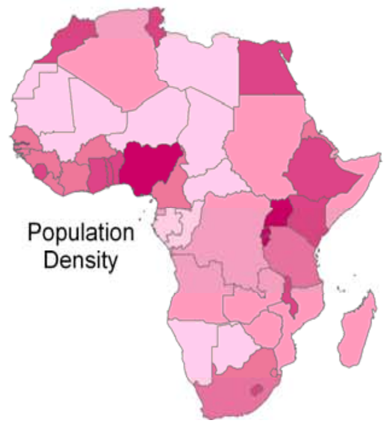
# *Spatial Determinants of Poverty in Africa*

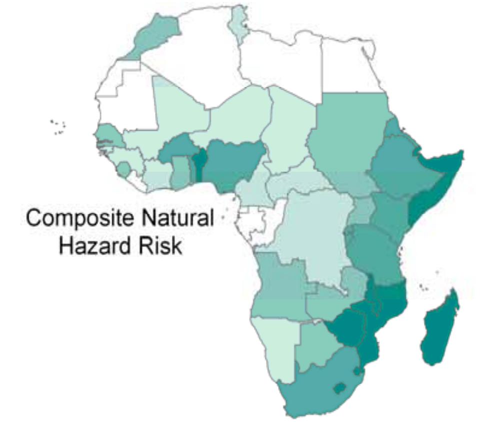
Control/Explanatory/Predictor Variables

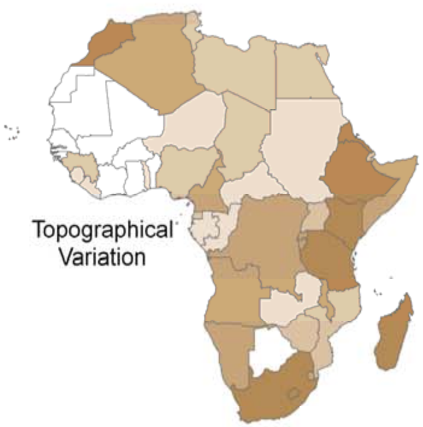


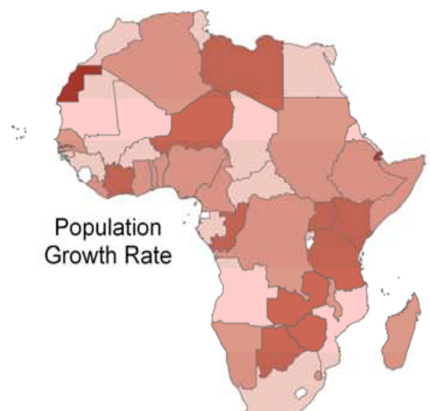









**...and 20+ other variables...**

Sources: CIESIN; FAO; SRTM; ESRI; UN; DCW

Geoinformation at the UN Economic Commission for Africa
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# Standard Cross-Country Linear Regression

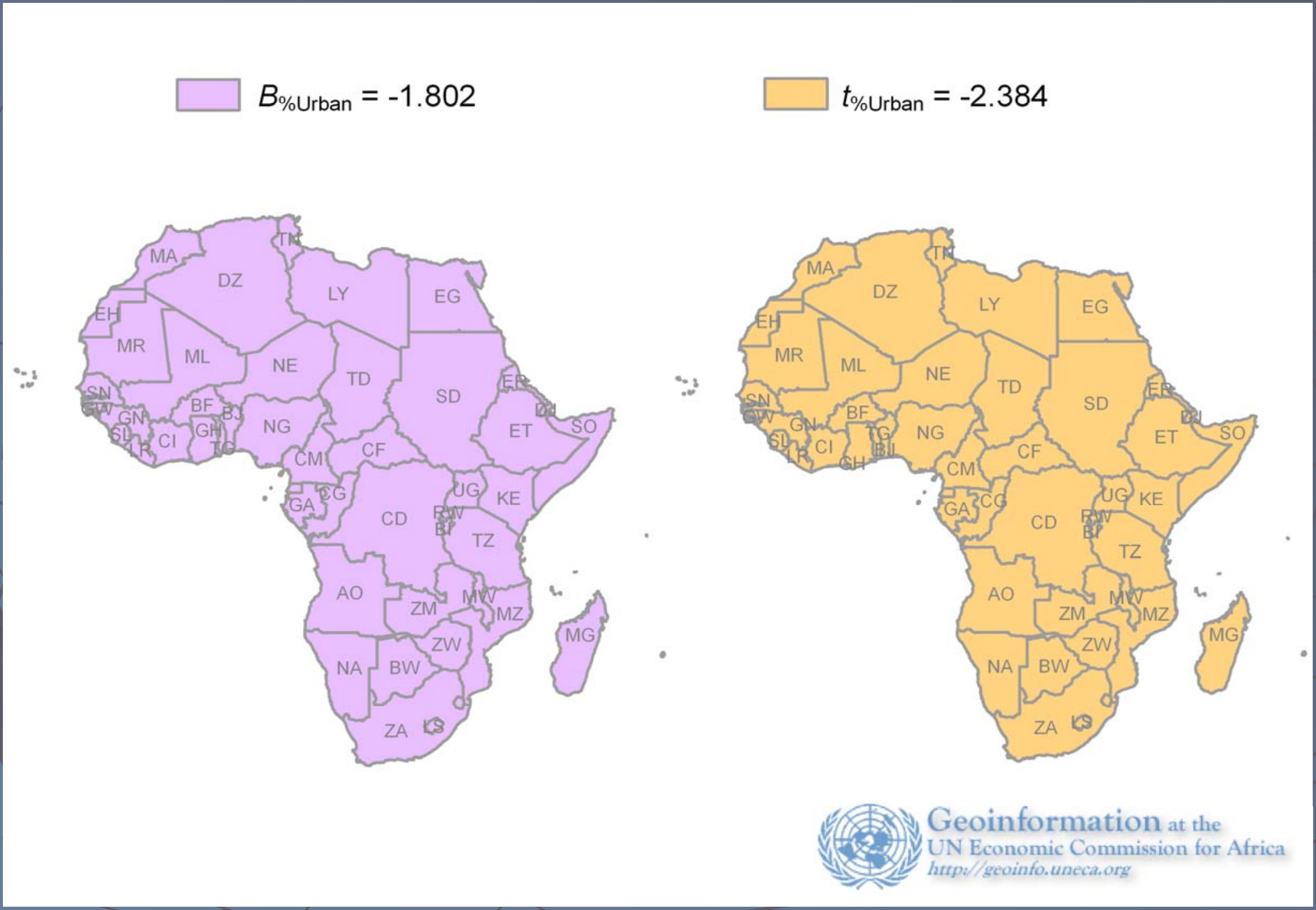
| Predictor | Coefficient | Std. Error | t* |
|---|---|---|---|
| Intercept | 0.228 | 0.755 | 0.302 |
| Demography/Settlement | | | |
| *Population Density (person/km²)* | -0.000 | 0.002 | -0.049 |
| *Pop. Growth Rate, 1960-2000* | -0.002 | 0.002 | -0.958 |
| *% Urban* | -1.802 | 0.756 | **-2.384** |
| Environmental | | | |
| *Mean Elevation (in metres)* | -0.000 | 0.001 | -0.525 |
| *Topography (std. dev. in metres)* | 0.000 | 0.001 | 0.302 |
| *Composite Natural Hazard Index* | 0.030 | 0.014 | **2.020** |
| Agricultural Resources | | | |
| *% Surface Freshwater* | 0.013 | 0.007 | **1.828** |
| *Mean Rainfall Runoff (mm/annum)* | 0.001 | 0.000 | 1.382 |
| *% Regosols* | 0.040 | 0.021 | **1.956** |
| *% Yermosols* | -0.024 | 0.014 | **-1.643** |
| Infrastructure | | | |
| *Road Network Density (km/km²)* | -0.072 | 0.036 | **-1.979** |
| Land Use | | | |
| *% Shrubland/Savannah* | 0.020 | 0.013 | 1.520 |
| *% Cropland* | 0.012 | 0.013 | 0.909 |
| *% Bare Soil* | 0.006 | 0.008 | 0.683 |

$t_{\alpha=0.05,n=30+} \geq 1.697$ **are in bold; $R^2$ = 0.412; *N* = 54**

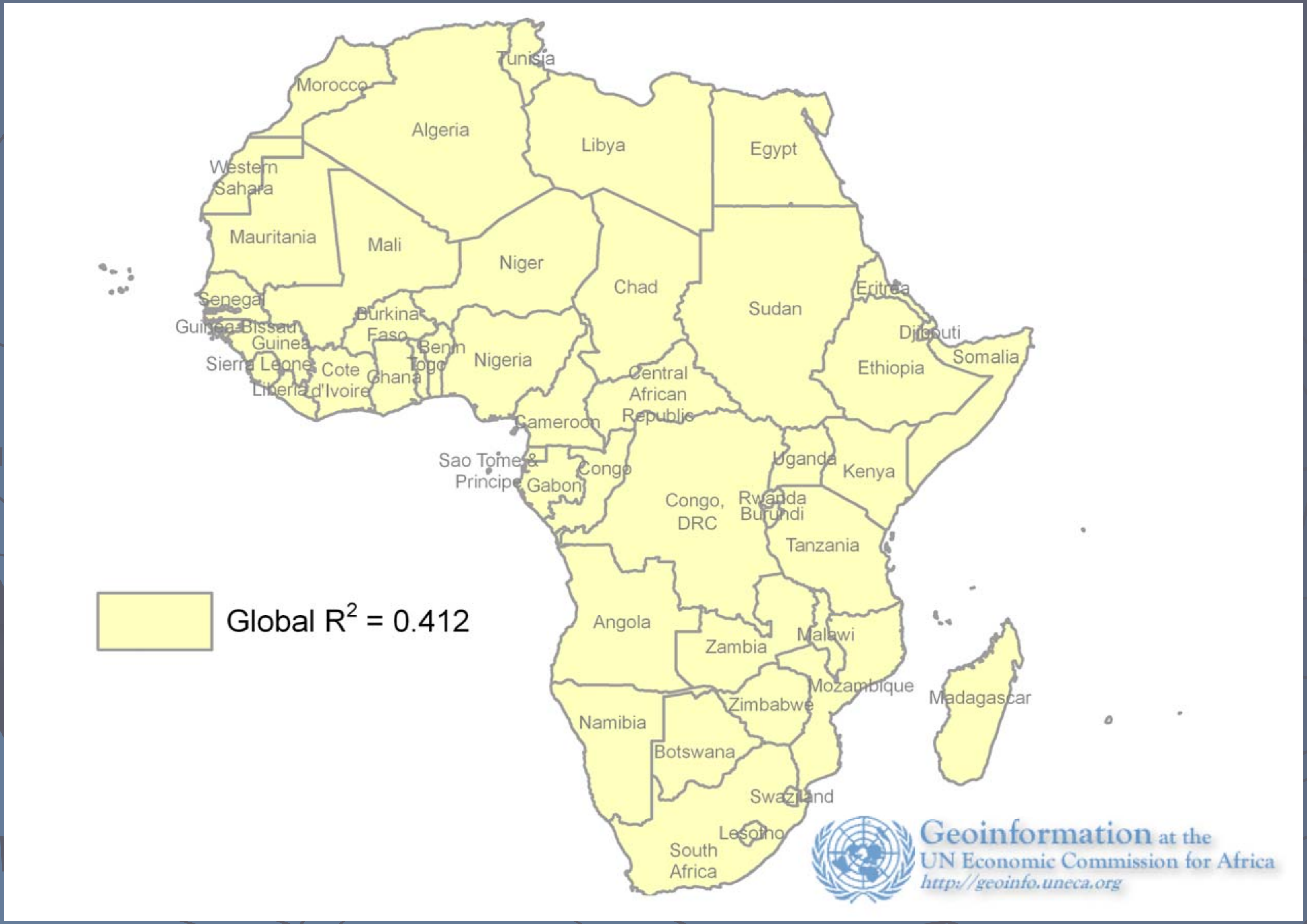
# Interpretation

- Urbanization is a salient predictor of poverty across Africa with a constant coefficient of -1.802
- Natural hazard risk is uniformly proportional to poverty with a coefficient of 0.03
- Transport infrastructure is an equally significant (and inversely related) predictor of poverty across the continent
- All other variables are insignificant predictors of poverty
- etc...

# Spatially Invariant Coefficients



# Spatially Invariant Explanatory Power



Is such an interpretation empirically sustainable?

# Geographically Weighted Regression

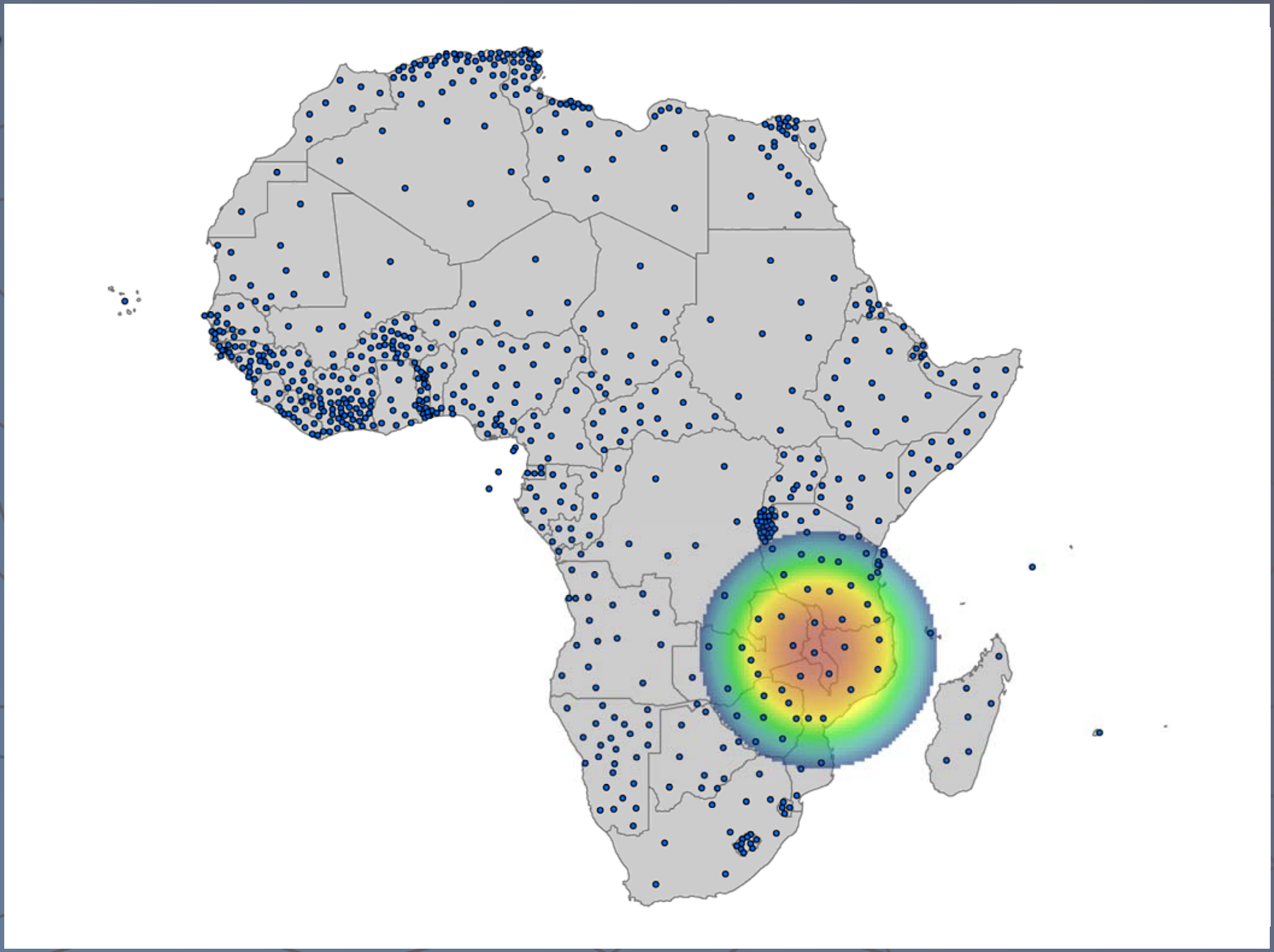
- The standard regression equation (in matrix form) $\mathbf{Y} = \mathbf{X\beta} + \varepsilon$ is estimated by $\hat{\boldsymbol{\beta}} = (\mathbf{X}^{\mathbf{T}}\mathbf{X})^{-1}\mathbf{X}^{\mathbf{T}}\mathbf{Y}$ yields a vector of parameters, $\hat{\boldsymbol{\beta}}$, that remain constant over space

- GWR weights observations around regression point $i$ (having easting $e_i$ and northing $n_i$) through a spatial weights matrix $\mathbf{W}$

$$\hat{\boldsymbol{\beta}}(e_i, n_i) = (\mathbf{X}^{\mathbf{T}}\mathbf{W}(e_i, n_i)\mathbf{X})^{-1}\mathbf{X}^{\mathbf{T}}\mathbf{W}(e_i, n_i)\mathbf{Y}$$

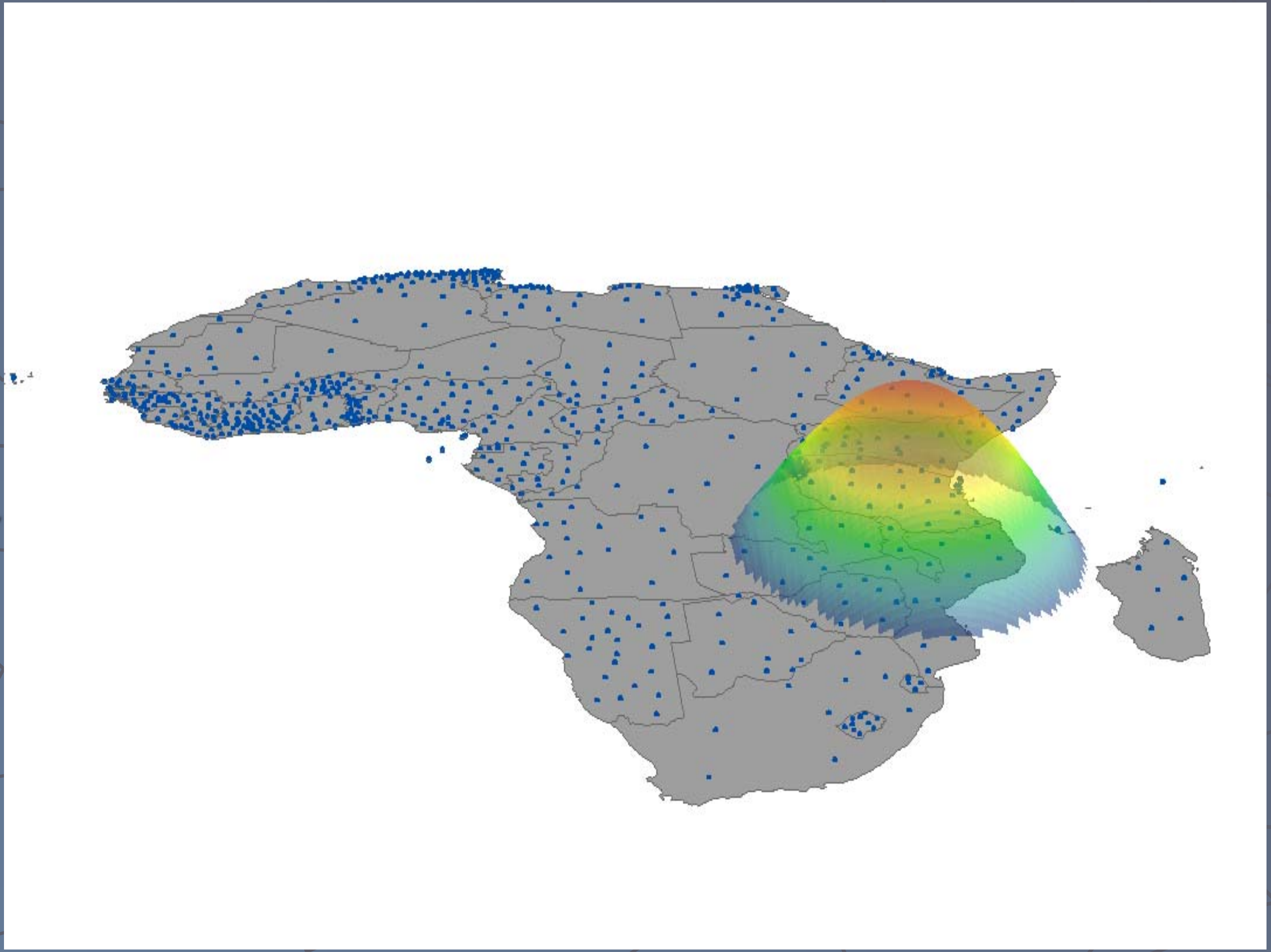
# Spatial Kernel (2D)

*Impose spatial kernels on our regression points, informed by theory, cross-validation, or arbitrarily.*



# Spatial Kernel (pseudo-3D)

*Kernels not only establish a bandwidth of inclusion but also weight the observations around the regression point by some function of their distance from it.*



# Geographically Weighted Regression

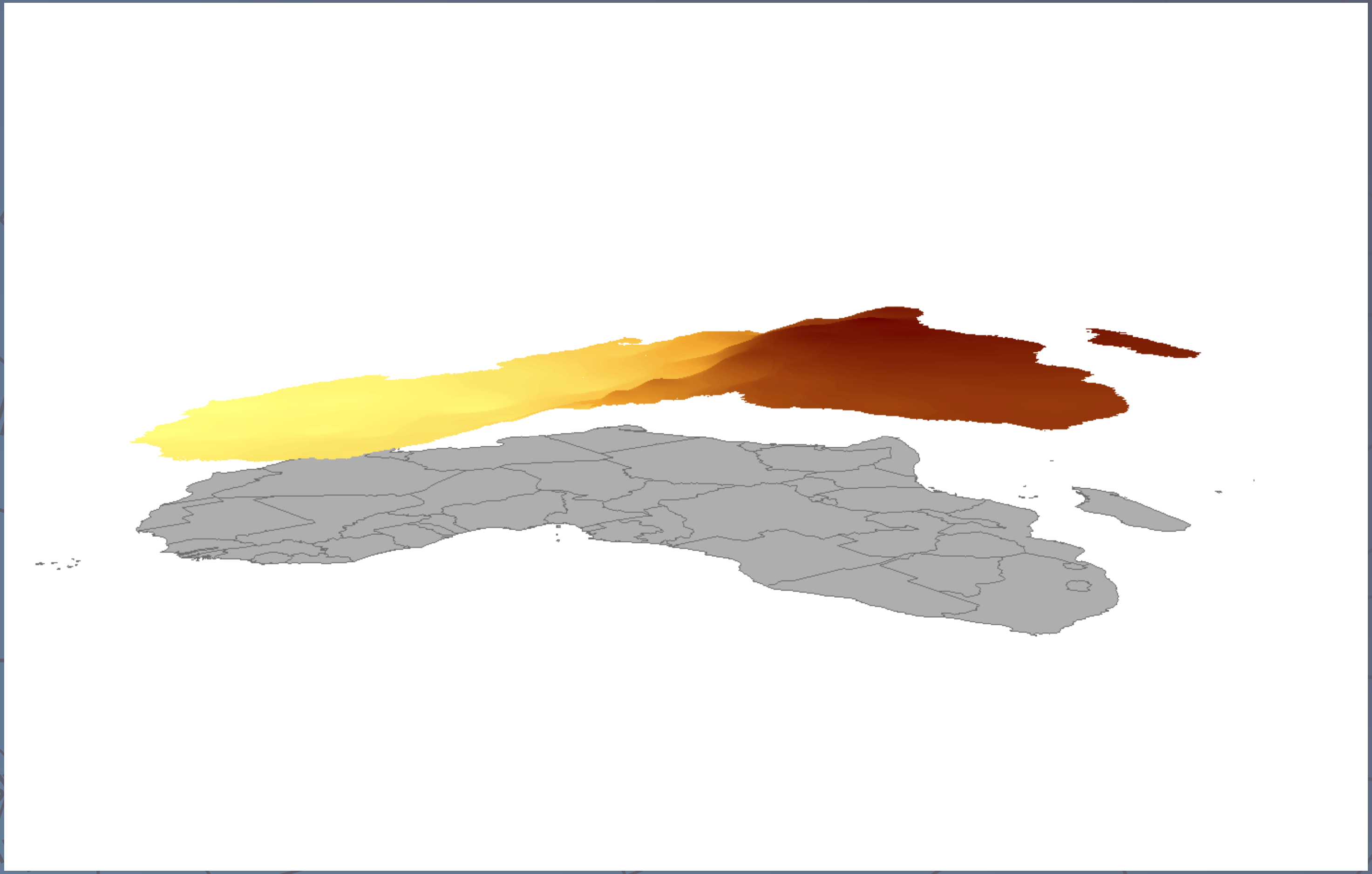
| Predictor | Min. | Lower Quartile | Median | Upper Quartile | Max. | Spatial Variability (p-value) |
|---|---|---|---|---|---|---|
| Intercept | -0.977 | -0.482 | -0.313 | -0.126 | 0.733 | 0.77 |
| Demography/Settlement | | | | | | |
| *Population Density (person/km²)* | -0.005 | -0.004 | 0.002 | 0.008 | 0.008 | 0.01 |
| *Pop. Growth Rate, 1960-2000* | -0.004 | -0.003 | -0.002 | -0.002 | -0.002 | 0.87 |
| *% Urban* | -3.752 | -3.567 | -1.712 | -0.712 | -0.409 | 0.00 |
| Environmental | | | | | | |
| *Mean Elevation (in metres)* | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.63 |
| *Topography (std. dev. in metres)* | -0.002 | -0.002 | -0.002 | 0.000 | 0.001 | 0.06 |
| *Composite Natural Hazard Index* | 0.018 | 0.028 | 0.038 | 0.051 | 0.060 | 0.19 |
| Agricultural Resources | | | | | | |
| *% Surface Freshwater* | 0.005 | 0.007 | 0.008 | 0.010 | 0.011 | 0.82 |
| *Mean Rainfall Runoff (mm/year)* | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.42 |
| *% Regosols* | 0.013 | 0.025 | 0.054 | 0.075 | 0.077 | 0.08 |
| *% Yermosols* | -0.039 | -0.037 | -0.035 | -0.013 | -0.003 | 0.35 |
| Infrastructure | | | | | | |
| *Road Network Density (km/km²)* | -0.109 | -0.038 | -0.022 | 0.000 | 0.083 | 0.57 |
| Land Use | | | | | | |
| *% Shrubland/Savannah* | -0.001 | 0.001 | 0.008 | 0.027 | 0.032 | 0.00 |
| *% Cropland* | -0.031 | -0.028 | -0.016 | 0.023 | 0.027 | 0.00 |
| *% Bare Soil* | 0.000 | 0.004 | 0.012 | 0.017 | 0.023 | 0.20 |

**Local R2 Range: 0.742 – 0.868; N Nearest Neighbours = 52**

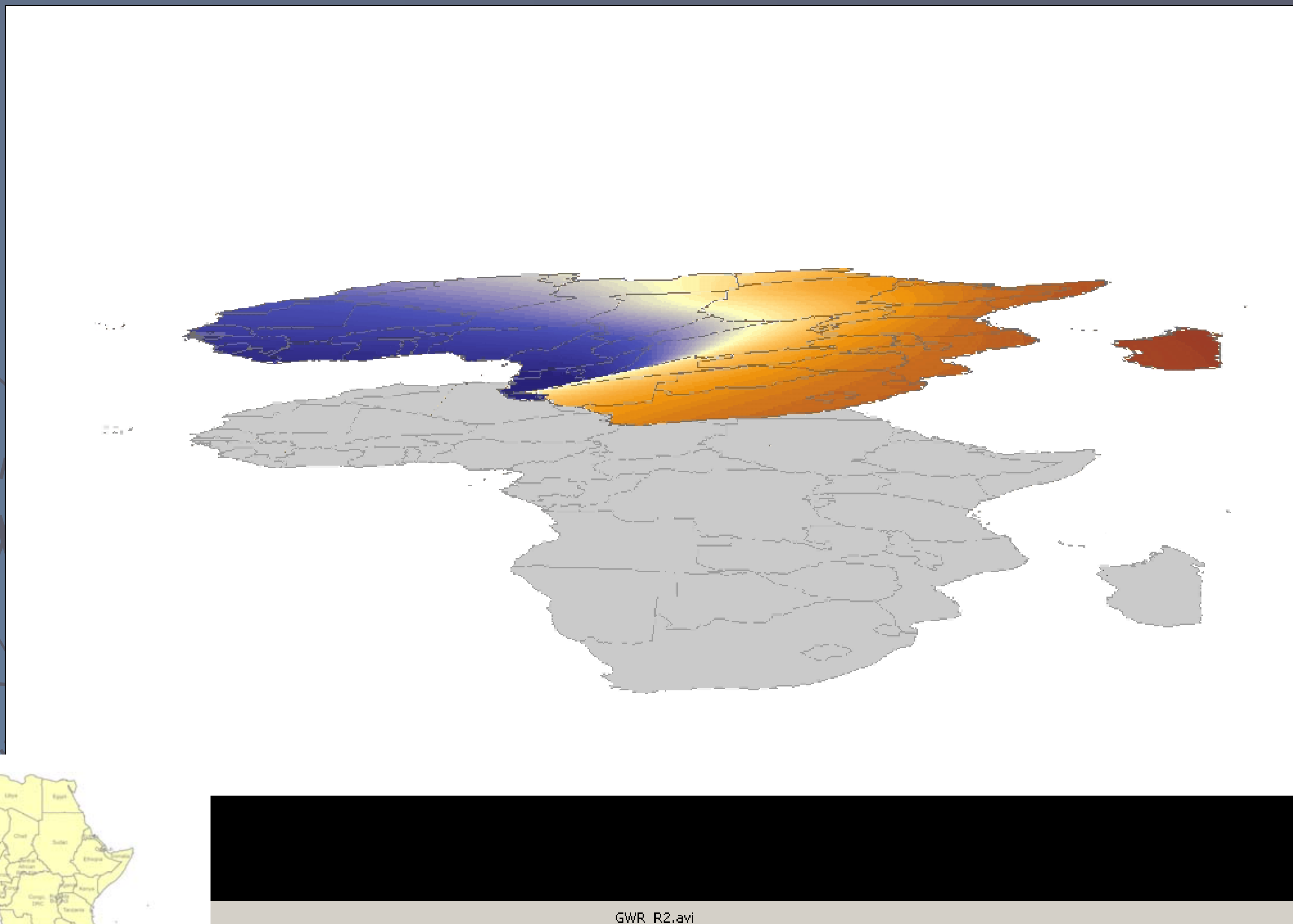
# Poverty-Urbanization Parameter Surface

GWRUrbanCoeff.avi

# Local Significance Estimtes from Local Coefficients and Std. Errors



# Local Adjusted $R^2$

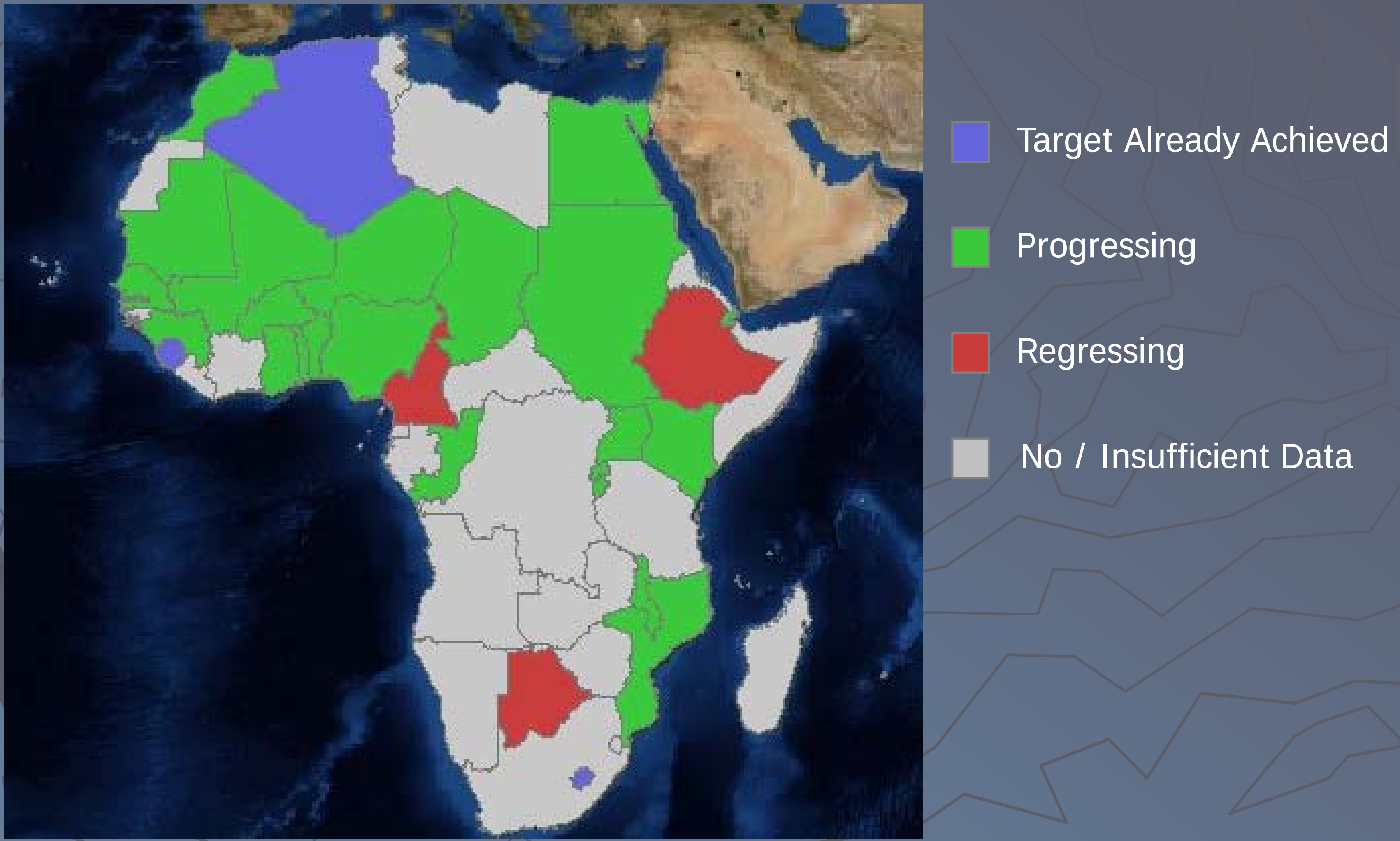



# Interpretation

- The poverty-urbanization relationship is directionally stable across the continent
- The magnitude of the effect is not and ranges from -3.752 to -0.409, a ratio of 9.
- But the local standard errors also vary spatially (not shown) and so the statistical salience of urbanization varies spatially
- Repeat this kind of interpretation for each variable
- The explanatory power of the model is also spatially variable

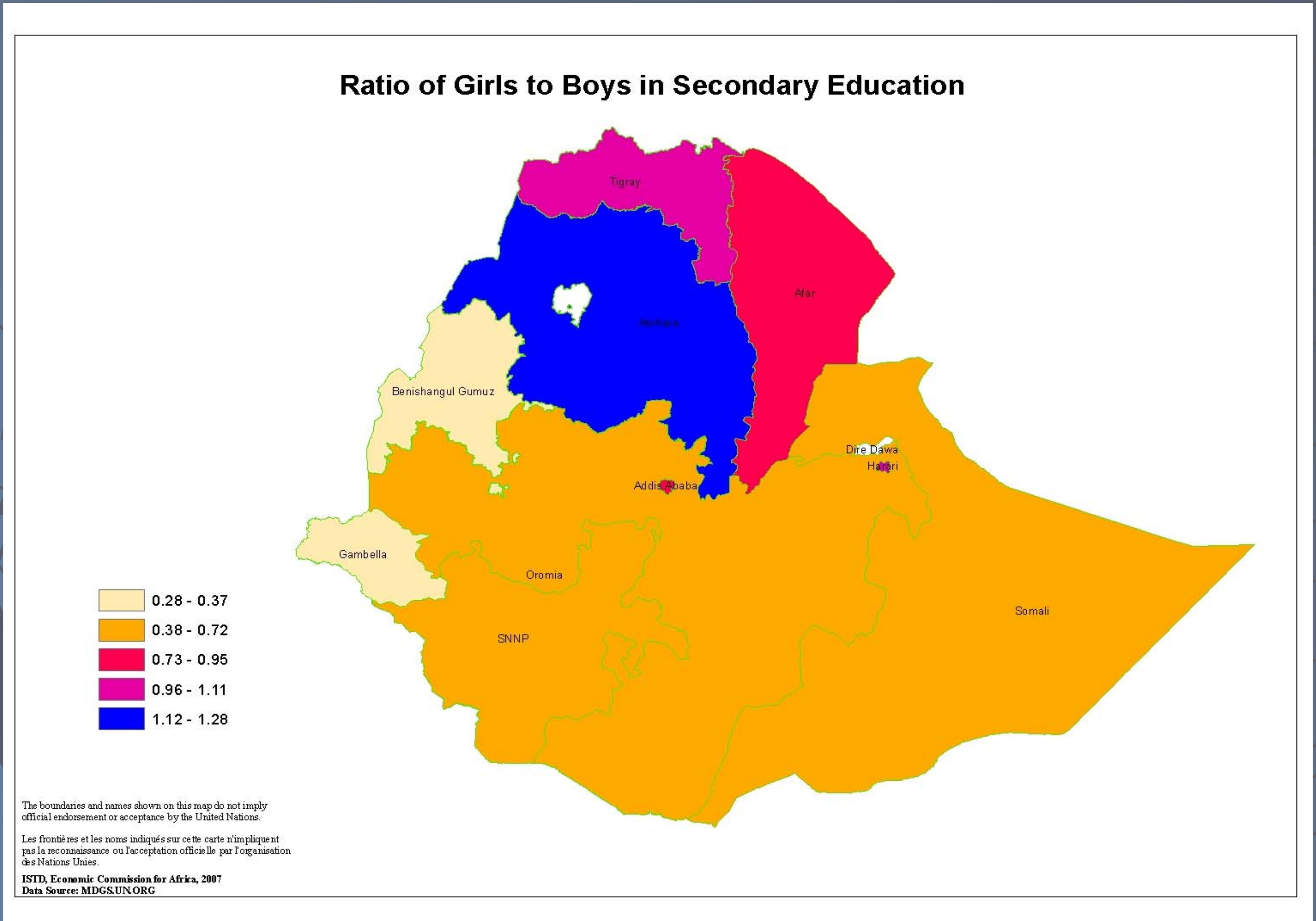
# Spatially Targetted Interventions

S613: Gender Parity Index in Secondary Level Enrolments



# Spatially Targetted Interventions

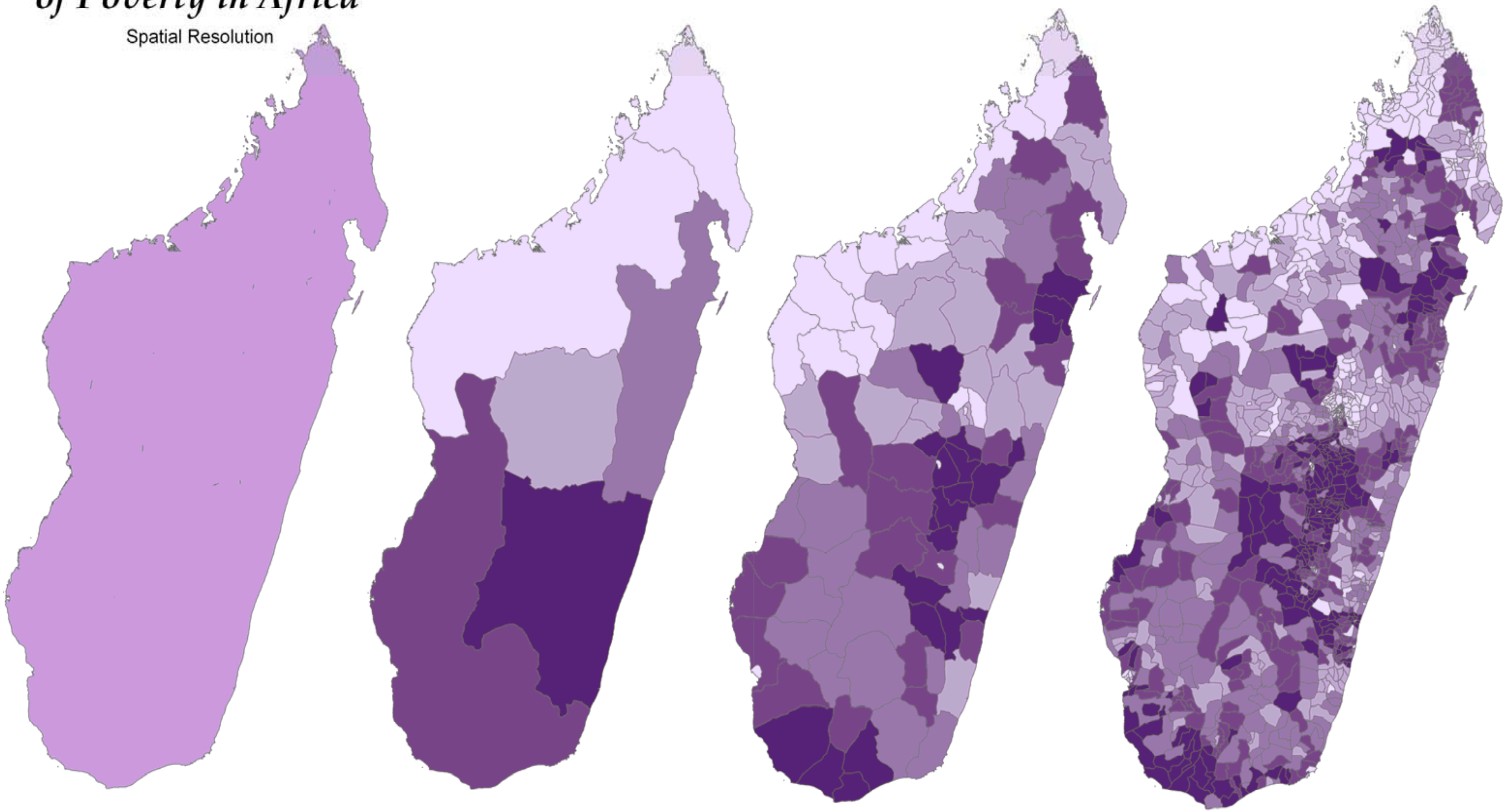
S613: Gender Parity Index in Secondary Level Enrolments



# *Spatial Determinants of Poverty in Africa*

Spatial Resolution

## Foster, Greer, Thorbecke Headcount Index



National
N = 1

Level 1: Faritany
N = 6

Level 2: Fivondrona
N = 111

Level 3: Firaisana
N = 1238

Sources: CIESIN Small Area Poverty Estimates

Geoinformation at the UN Economic Commission for Africa
http://geoinfo.uneca.org

# Policy Implications

- GWR poverty models estimated with GWR may offer spatially prescriptive cues on local programme design and delivery
- Geographic targeting of specific intervention mixtures that are place and scale specific
- Mitigate ineffectual and inefficient spend
- Don't assume stationarity; test for it

# Contacts

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