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Extended spatial logit models of deforestation due to population and relief energy in East Asia

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This work is …

"Non-linear regression models to identify functional forms of deforestation,"

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Outline

- Introduction
- REGRESSION MODELS:
  Response variable: forest areal ratio
  Explanation variables:
  human population density and relief energy
- Spatially-dependent models
- Models examined by four test fields in East Asia

Various causes of deforestation

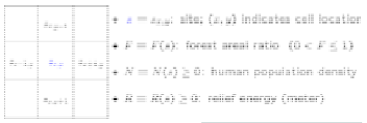
- larger cultivated lands
- larger grazing fields
- fuel wood requirements
- logging
- larger residential area (reclamation)
- airborne pollutants

related to human population growth

(Lambin, 1997; Myers, 1990)

Our Aim:

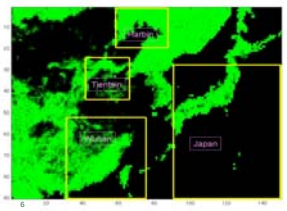
Find functional form: $F = F(N, R)$



- $s = s_{i,j}$: site; (i, j) indicates cell location
- $F = F(s)$: forest areal ratio $(0 < F \leq 1)$
- $N = N(s) \geq 0$: human population density
- $R = R(s) \geq 0$: relief energy (meter)

Hiroshima Dataset: ≈ 1km²
World Dataset: ≈ 37km²

Test areas in East Asia



Extended logit transformation ("eLogit")

$$\text{logit} = \log\left(\frac{F}{1-F}\right)$$

The ordinary logit

$$L = \log\left(\frac{F+0.5}{1-F+0.5}\right)$$

Extended logit

valid for cases $F = 0,1$

$$F = \frac{2}{1+e^{-L}} - 0.5$$

Preliminary search for the functional forms

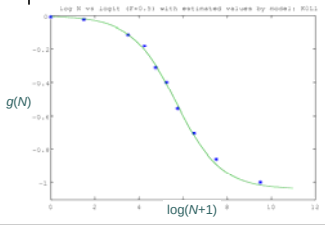
$$L(N,R) = \beta_0 + g_0(N) + h_0(R) + e$$

$$g_0(N) = \sum_{k=1}^{G} \psi_k \mathbf{I}(N \in [n_{k-1}, n_k)) \quad : \text{step function}$$

$$h_0(R) = \sum_{k=1}^{H} \omega_k \mathbf{I}(R \in [r_{k-1}, r_k)) \quad : \text{step function}$$

Functional form: $g(N), N$:population

Hiroshima

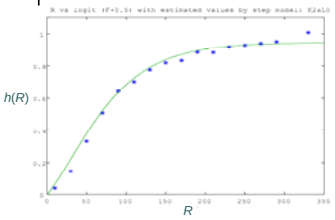


Candidate models for population

$$
\begin{aligned}
g_0(N) &= \text{step func.} \\
g_1(N) &= -a\log(N+1) \\
g_2(N) &= -\frac{\beta_1}{1+\exp(\beta_2-\beta_3\log(N+1))}+\frac{\beta_1}{1+\exp(\beta_2)} \\
g_3(N) &= \gamma\{1-\exp(a\log(N+1))\}
\end{aligned}
$$

Functional form: $h(R), R$: relief

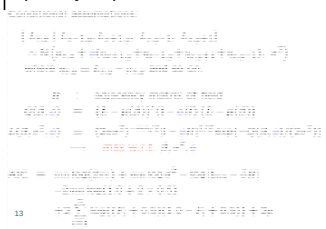
Hiroshima



Candidate models for relief

$$
\begin{aligned}
h_0(R) &= \text{step func.} \\
h_1(R) &= \mathbf{I}(R>\theta)\cdot\delta\log(R-\theta+1) \\
h_2(R) &= \mathbf{I}(R>\theta)\cdot\delta\log\binom{R}{\theta} \\
h_3(R) &= \beta_3\exp\left(-\beta_1 e^{-\beta_2 R}\right)-\beta_3\exp(-\beta_1) \\
h_4(R) &= \frac{\beta_1}{1+\exp(\beta_2-\beta_3 R)}-\frac{\beta_1}{1+\exp(\beta_2)}
\end{aligned}
$$

Conditional and joint distributions of spatially-dependent models



Estimated best eLogit model

$$g_2(N)+h_2(R)$$

$$
L(N,R)=\beta_0+\frac{\beta_1}{1+\exp(\beta_2-\beta_3\log(N+1))}-\frac{\beta_1}{1+\exp(\beta_2)}+\mathbf{I}(R>\theta)\cdot\delta\log\left(\frac{R}{\theta}\right)+\epsilon
$$

Estimated Parameters

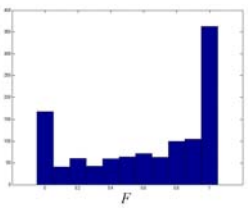
$g_2(N)+h_2(R)$ spatial

Param.	Japan ($\cong 37km^2$, $N=354$)	Tientsin ($\cong 37km^2$, $N=391$)
β_0	0.7163	-0.1297
β_1	27.07	0.3556
β_2	12.41	53.44
β_3	1.004	9.175
δ	0.1541	0.7092
θ	199.0	646.8
ϕ	0.1874	0.2491
σ^2	0.06177	0.1611

Concluding remarks

- eLogit models of forest areal rate F are estimated by
  N (population) and R (relief)
- Functional form of N (population) is satisfactory
- eLogit models are superior to
  * the additive models, and
  * the ordinary Logit models

Data distribution $0 \le F \le 1$, Wuhan with 1136 samples



Remaining problems

- Spatially-dependent inflated beta distribution
- Model verification in other areas
- Dataset review (esp. gridded population)
- Random effect model approach to population
- Theoretical aspect of the functional forms
- Verification of another form: $(\log(N+1))^{\beta}, R^{\beta}$
- Different slope-effect incorporation
- Round disk-shape test field selection
- Eight neighbor case of spatial model